Special Section: 1990 SUMMER GUIDE TO ASTRONOMY

# ASTRONOMY®

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## How to Star-Test Your Telescope

May 1990

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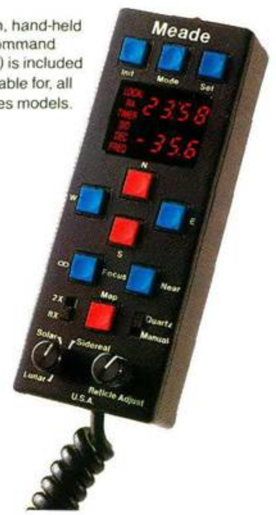

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| **2120/Model 50** | 10" | f/10 | LX6 | Standard | Field | 9 x 60mm Polar | 2" | SP 26mm | Package A |
| **2120/Model 50H** | 10" | f/10 | LX6 | Superwedge | Field | 9 x 60mm Polar | 2" | SP 26mm | Package A |
| **2080/Model 56** | 8" | f/6.3 | LX6 | Standard | Field | 9 x 60mm Polar | 2" | SP 26mm | Package A |
| **2120/Model 56** | 10" | f/6.3 | LX6 | Standard | Field | 9 x 60mm Polar | 2" | SP 26mm | Package A |
| **2120/Model 56H** | 10" | f/6.3 | LX6 | Superwedge | Field | 9 x 60mm Polar | 2" | SP 26mm | Package A |
| **2080/Model 70** | 8" | f/10 | LX6 | Standard | Field | 9 x 60mm Polar | 2" | Package B | Packages A & C |
| **2120/Model 70H** | 10" | f/10 | LX6 | Superwedge | Field | 9 x 60mm Polar | 2" | Package B | Packages A & C |
| **2080/Model 76** | 8" | f/6.3 | LX6 | Standard | Field | 9 x 60mm Polar | 2" | Package B | Packages A & C |
| **2120/Model 76H** | 10" | f/6.3 | LX6 | Superwedge | Field | 9 x 60mm Polar | 2" | Package B | Packages A & C |

[1] **Package A:** 115v AC and 12v DC power cords; battery pack. **Package B:** SP 26mm; SWA 40mm; UWA 6.7mm; UWA 14mm. **Package C:** #1200 Electric Focuser; Off-Axis

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|---|---|---|---|---|
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| Optional | Optional | Optional | Optional | |
| Optional | Optional | Optional | Optional | |
| Optional | Optional | Optional | Optional | *The lowest-cost f/6.3 Schmidt-Cassegrain ever!* Meade f/6.3 models reduce astrophoto exposure times by 60% compared to f/10 models. Eyepiece for eyepiece, images are 2½ times brighter and fields of view 59% wider. |
| Optional | Optional | Optional | Optional | |
| Optional | Optional | Optional | Optional | |
| Standard | Standard | Optional | Optional | 50-series models include hand-held Electronic Command Center and Electric Declination Motor for full dual-axis electronic control of the telescope. Use the 2X speed for precise corrections during astrophotography; flip to 8X speed for image centering and field scanning. |
| Standard | Standard | Optional | Optional | |
| Standard | Standard | Optional | Optional | |
| Standard | Standard | Optional | Optional | Identical to 50-series in specifications, including dual-axis Electronic Command Center, but with fast, wide-field f/6.3 optical system. 2″ multi-coated diagonal mirror permits use of wide-angle 2″-barrel eyepieces as well as standard 1.25″-barrel eyepieces. |
| Standard | Standard | Optional | Optional | |
| Standard | Standard | Optional | Optional | |
| Standard | Standard | Standard | Standard | Meade 70- and 76-series are the most advanced and fully-equipped instruments of their types currently available. Included is virtually every accessory required for a lifetime of advanced photo and visual observing: the CAT Computer Aided Telescope system with its 8,199-object memory; Off-Axis Guider/Illuminated Reticle Eyepiece assembly for long-exposure astrophotography; an assortment of 4 superb eyepieces; and #1200A electric focuser. |
| Standard | Standard | Standard | Standard | |
| Standard | Standard | Standard | Standard | |
| Standard | Standard | Standard | Standard | |

Guider; MA 12mm Illuminated Reticle Eyepiece. [2] Electronic Command Center. [3] Electric Declination Motor System. [4] Computer Aided Telescope System. [5] Digital Readout System.

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**ON THE COVER:** One of the most striking planetaries in a small telescope is the Dumbbell Nebula in Vulpecula. (See page 64.) Canada-France-Hawaii Telescope Corporation.

**THE GRANDEUR** of the star-rich summer Milky Way is the perfect subject for wide-field piggyback astrophotography. (See page 70.) Photo by Jerry Schad.

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The Audit Bureau

## Behind the Scenes

# SUMMERTIME TREATS

When I got out of bed this morning I went to the window to see Venus shining in the eastern sky, a dazzling point of light against a background of summer stars. By the beginning of May, I thought, I'll be watching Comet Austin before dawn from the backyard beside our garden shed where I have a clear view of the eastern sky. With my telescope beside me and binoculars hung around my neck, I'll be estimating the comet's brightness.

Join me, won't you, these May mornings, for Comet Austin. You'll be wherever you are and I'll be here, but we'll both be watching the comet. Come out under the stars and share this comet with me and millions of others around the world.

As I write this month's Behind the Scenes, however, it is February and summer seems far away. Yet as I looked out my window this morning, the constellations Cygnus, Aquila, and Scorpius — redolent of hot July nights — hung in the chill air over a fresh snowfall. As you read this issue of ASTRONOMY summer will be just around the corner — time to start thinking about getting out and doing some serious stargazing, making your vacation plans, and meeting some other astronomers.

ASTRONOMY's Summer Guide lists hundreds of summertime treats for you all across the country — star parties, astronomy conventions, and astro-places to go to and astro-things to see. To help you get the most from the Summer Guide, we've made it a special pull-out section of the magazine. If you've been hoping to meet other people interested in astronomy, you'll find an astronomy club listed somewhere near you. As for summertime events, will we see you at the Riverside Telescope Makers Conference in Big Bear, the Astronomical League Convention in St. Louis, or the Midwest AstroFest near Kankakee?

Finally, I'd like to draw your attention to a small but important item in AstroNews on the newly formed Telescope Optics Manufacturers Association. TOMA was formed to set optical standards in the astronomical telescope industry. These standards will insure that you, the telescope buyer, will receive a quality telescope when you buy from a TOMA member firm. ASTRONOMY heartily supports the Telescope Optics Manufacturers Association and its mission in the firm conviction that a satisfied telescope buyer will remain a satisfied amateur astronomer for many years.

Sincerely,

Richard Berry

Richard Berry
Editor-in-Chief

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## Letters

### Find that Magnification

I think the following statement in Michael Porcellino's article on the art of seeing is a little dogmatic and needs some discussion: "If you use low magnification you maximize contrast between an object and the sky background. This is why many nebulous objects are best viewed at low magnification and seem to disappear when viewed at higher powers."

First, let's agree that on a given night the contrast between a nebulous object and the background is constant. I suggest that the maximum visibility of the object does *not* occur when it is brightest (at low power) because the background is brighter in the same ratio. As you raise the power, the object appears larger and larger and the sky background eventually becomes black. You'll see more detail because the object is larger and the contrast is constant. You will lose contrast if you go past "black sky."

My conclusion is that for the best low-power viewing, use the highest power that still shows the complete object when just reaching a black sky background. — *Al Nagler, Spring Valley, New York*

### The Astrology Debate

I enjoyed John Mosley's article on how to debate with astrologers (Viewpoint, February 1990). I am afraid, however, that his truism — "If you try to counter a person's emotional beliefs with rational arguments, you'll get nowhere" — also applies to his short, logical, and truthful arguments against astrology. — *S. J. Davidson, Fresno, California*

Good luck to John Mosley in his quest for rational people. His three non-statistical arguments against astrology are good ones, and here are three more.

Compared to advances made by astronomers, what progress have astrologers made in making their predictions more accurate? What effect would human space travel have on an astrological chart when both distance and time distort astrological positions as seen from the spacecraft? If astrologers wanted to, they could confirm astronomical discoveries via traditional technology and research. Why can't anyone confirm the validity of astrological predictions? — *Evans H. Burn, South Hadley, Massachusetts*

John Mosley's opinion about debat-

# Genesis Owner Turned Into Zombie!

Gentlemen:

I would like to say a few words about my new Genesis. I live in a relatively light polluted area, and own an 8" SCT which I have used for about two years. During this time there have been many deep sky objects which I have been unable to locate from my back yard.

I bought Genesis because I wanted a telescope that I could set up quickly to use at home on week-nights. When I began using Genesis, a few weeks ago, I was surprised to find many objects that have eluded me during the past two years. I was even more surprised when I realized that I had been looking in the right places all the time. These objects showed up in Genesis, but not in my 8" SCT.

My back yard experience with Genesis encouraged me to take it to my dark sky observing site which is, at an elevation of 5000 feet above sea level, in the Sierra Nevada Mountains. What I saw there was, in many cases, better than photographs in magazines. I was able to resolve globular clusters to a greater degree than publications indicate.

I didn't expect Genesis to be this good. It really is better than I imagined.

There does seem to be one problem with Genesis. My short week-night observing sessions have become anything but short, and I frequently arrive at work feeling and looking very much like a zombie. I guess that no telescope can solve all of your problems. In any case, thanks for the ones you did solve.

*- George N. Storm, California*

Photo by Jim Riffle

## Unsolicited comments from warranty cards

- *It's beautiful, from case to scope.* C.C. The Netherlands
- *Fantastic! Great photo resolution, best optics ever owned and I'm a Hasselblad & Nikon fan. Now my best item.* D.B. New Jersey
- *This is my 1st scope and I'm having a wonderful time finding the limits of the instrument and my locating abilities.* G.P. New Jersey
- *Very pleased with your new improvements.* J.F. California
- *Even though cost was more than an 8" SCT with mount, quality & convenience won out. I will only use Tele Vue optics, mount and accessories.* W.B. Indiana
- *The telescope lives up to its expectation.* T.W. England
- *Wanted a 2nd telescope that was portable, delivered wide fields and superb images. Genesis is all I hoped for. The sharpness is astonishing and it's very portable.* G.H. Canada
- *Sold my 8" SCT looking for better images.* P.F. New York
- *Fantastic! My wife could not see Trapezium etc. with old scope. Now can't get her away from eyepiece: you have right to be enthused about your product.* W.J. Canada
- *I just wanted to have one excellent telescope to do astrophotography. Fantastic. Awesome.* J.J. California
- *Beautiful equipment - Total satisfaction with first use. Keep up the good work.* M.C. Ohio
- *I wanted a very high quality refractor. I was told by many - "This is it." This is a beautiful instrument!* M.F. Florida
- *Remarkable! I always wanted a 4" fluorite refractor. Sold my (8" SCT).* T.S. Indiana
- *Compactness & quality - a beautiful, fantastic instrument.* J.V. The Netherlands

- *It's the best 4" refractor made.* A.A. California
- *I was looking for the best first telescope I could buy. Something small. I never saw images clearer and more distinct than in Genesis.* G.D. Canada
- *Genesis is the only scope in the race. I wanted the best and believe I got it.* E.S. Australia
- *As the apparent equal of a (Maksutov), with the added RFT capability, Genesis is 'the', to me, obvious choice for portable astronomy. I'm completely satisfied.* R.A. Georgia
- *Very Impressive - my first view was of Pleiades with a 40mm Wide Field. The observation was remarkable, crisp, bright and jewel-like.* P.L. Massachusetts
- *The best on the market.* E.B. England
- *I bought this telescope without having seen it in-person, based on its specification & your reputation for quality. As usual, I got more than I expected with Tele Vue products...* K.L. Texas
- *My friend borrowed it & won't give it back!!* T.L. Canada
- *I wanted portability and very high quality optics. I have waited many years to be able to afford this telescope, - it was worth waiting for.* P.H. Australia
- *Superior to other 4" scopes on offer.* Z.V.S. South Africa
- *Had SCT, poor contrast/resolution. Tele Vue just the opposite, also it's more portable.* W.S. Connecticut
- *I purchased this instrument because:*
  *1) Apo-refractor - basic design*
  *2) Tele Vue reputation*
  *3) Dealer owns same model*
  U.B. Canada
- *Genesis is as good as gold...Maybe better!* F.G. California
- *I compared specs of Tele Vue vs (other high performance refractors); T-V best choice for $.* R.A. New Hampshire
- *Magic.* C.H. England

My sincerest thanks to all who've written us with such kind comments. I look forward to reading yours.

Al Nagler

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ing astrology from the viewpoint of an astronomer points to a common, ill-conceived approach too often used by the scientific community. Astronomers try to explain the universe in accordance with the laws of nature, whereas astrologers try to explain individual human futures as determined by that same universe.

Astronomers have no luck debating astrologers because astrology is based on an unprovable belief. If Mr. Mosley debated the astrologers based on their accuracy of predictions, he would stand a better chance winning over a crowd that rules by emotion. — *Kevin F. Owens, Arlington, Virginia*

One crucial point failed to come out in John Mosley's Viewpoint: The Sun does not appear in the proper zodiacal sign relative to astrology's definition of dates. Since Ptolemy's time, precession has skewed the Sun's position in the heavens, and the Sun lags the horoscope by over three weeks.

For example, someone born between March 21 and April 19 is an Aries. However, the Sun does not enter Aries until April 17 or 18. This ought to be sobering news to anyone who feels that astrology has some meaning. — *Randy Sheidler, Gallipolis, Ohio*

**Corrections**

In the table on page 62 of the January 1990 issue, the labels *Venus* and *Sun* at the heads of their respective columns should be transposed; i.e., the left two columns give the positions for the Sun.

An incorrect unit was used in the AstroNews story "Intergalactic Radio Glow Discovered," on page 16 of the February 1990 issue. The estimated strength of the intergalactic magnetic field should have been given as 0.3 to 0.6 *microgauss,* not gauss.

In "Find a Supernova Remnant," also in the February 1990 issue, one of the featured objects, NGC 6888, is actually a Wolf-Rayet star (HD 192163) experiencing high mass loss.

In the February Reader Reports column, the drawings of Saturn were made by Michael Sweetman.

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*ASTRONOMY welcomes comments, suggestions, and additional information on articles and astronomy in general. Send your letters to: ASTRONOMY Letters, P.O. Box 1612, Waukesha, WI 53187. Letters may be edited for length and clarity.*

## Viewpoint

# ASTRONOMY AND HAPPY SURVIVAL

*by Yervant Terzian*
*professor of astronomy and chairman of the Astronomy Department at Cornell University*

According to current theory, matter was created from energy at the time of the Big Bang. As the hot early universe expanded and cooled, it separated into pieces that later formed the hundreds of millions of galaxies we now see. One such galaxy was the Milky Way, which in turn spawned some 200 billion stars, of which the Sun is one. Around the Sun, a small planet was formed on which biological evolution has progressed during the last few billion years. You and I are part of the result.

**Astronomy is the most imagination-stirring way to teach science to young people.**

Now here we are, atoms from the Big Bang, an intelligent and technological civilization of more than 5 billion, fast-multiplying, and largely unhappy human beings. This long evolution has now given us the wisdom to ask what is it that we want. We all want survival, of course, but survival on our own terms, for ourselves and generations to come. I, and probably you, would want those terms to be happy and democratic.

If our most fundamental wish is a happy and democratic survival, this can be achieved only by an informed society. To be informed we must be educated, and in today's world no one ignorant of science can be considered educated. Hence, science education appears fundamentally important to a happy and democratic future.

Alas, we now find that while science and technology have advanced very fast, most people's understanding of them has not. Many have been very slow in keeping up with science developments and their implications for society. Science education is severely lacking when the vast majority of the population believes in such ideas as astrology and aliens in UFOs. Only a minority of the populace has much understanding of the greenhouse effect, nuclear winter, genetic engineering, or nuclear fusion, to name a few subjects that need intelligent response from the public. Recent nationwide surveys have shown that most educated people have no idea why there are seasons on Earth, and about 94 million U.S. citizens do not know the Earth revolves around the Sun once a year.

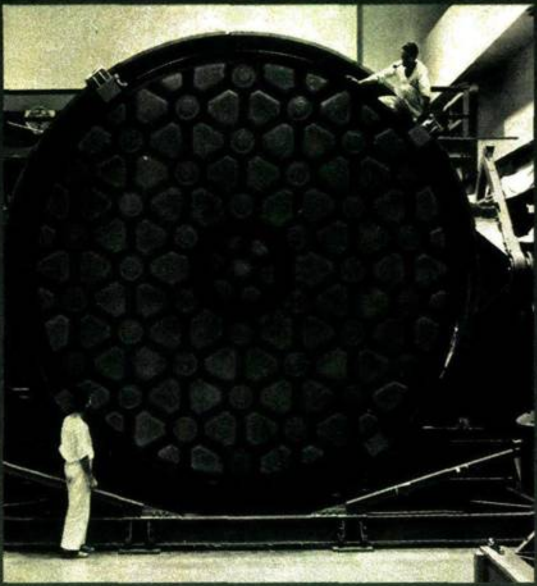
Recent reports on the status of education are shocking and point to a rapid decline of interest in the sciences by young students and the general public. How can we hope for a happy and democratic future when the people who must make decisions are becoming more ignorant of science?

What should we do? It is clear to me that we need to instill a sense of joy in learning science. When I was a boy I studied astronomy because I was curious about the universe and the ultimate puzzle of existence. Astronomy is a majestic observational science and to the general public is perhaps the most interesting and stimulating of all the sciences. Astronomy is also one of the most motivating, imagination-stirring, and exciting subjects that can trigger a love of science in the mind of a young person.

I suggest that all of us embrace the idea of introducing the study of the universe in every elementary and high school. This would help foster students' critical and analytical thinking and a creative involvement with the scientific method. I also propose that every school have a telescope. Who hasn't been thrilled by a view of Saturn's rings or the intricate stellar jewelry of a star cluster? I think we should all get involved at local and state levels and urge the use of astronomy in the schools as a way of teaching science to young people.

For me, any happy survival will also include the joy of poetry and music. It would be a great mistake to divorce the sciences from the humanities. However, unless we use the benefits of science and technology intelligently, I see little hope of achieving a happy and democratic human civilization. And without *that,* we will not be able to appreciate the arts and humanities.

Astronomers of all kinds — professional and amateur — are in an enviable position. We are "possessors" of a *uniquely popular* science and therefore can contribute significantly to a national and worldwide effort in science education.

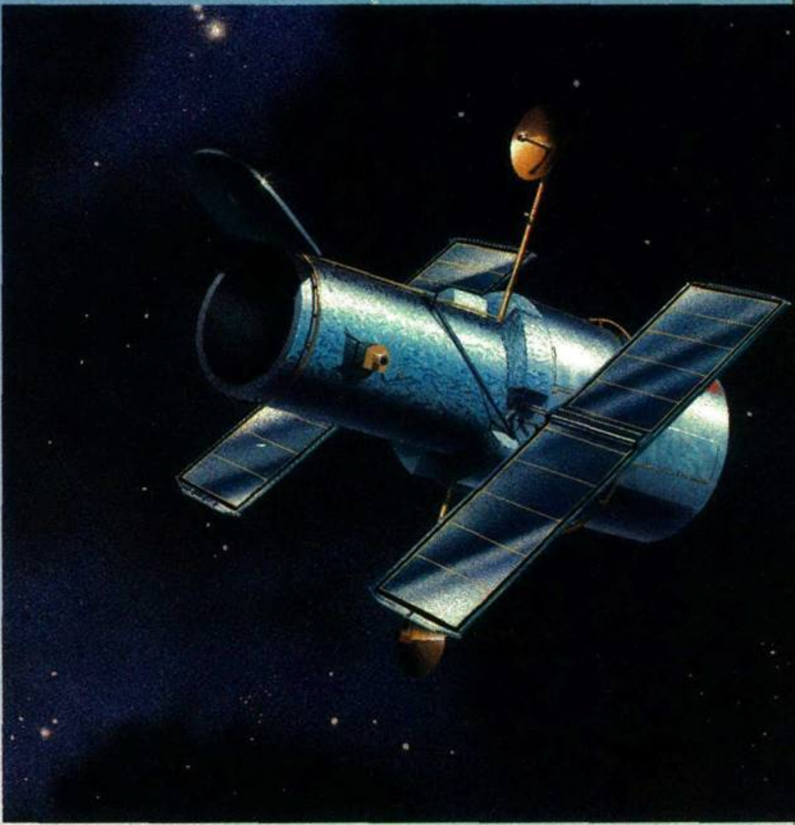


In 1934, Corning successfully cast the famous 200" Pyrex borosilicate mirror blank for the Hale telescope on Mt. Palomar. This mirror remains the largest blank in the Western world today.

This year, the Hubble Space Telescope which utilizes a 2.4 meter primary mirror blank fabricated using Corning's ULE zero expansion glass will be launched. This mirror is the world's largest lightweight mirror blank — weighing only about 20% of an equivalent size solid.

# *From HALE to HUBBLE*

## *Serving Astronomy for Over 50 Years*



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# GIANT HYDROGEN SHELL FOUND IN ORION

Astronomers have discovered a giant, rapidly expanding shell of hydrogen gas and an extensive "atmosphere" of atomic hydrogen in the constellation Orion. The shell is situated along the edge of a giant molecular cloud, a cool cloud of dense interstellar matter that is the birthplace of stars, and appears along the same line of sight as the two eastern stars of Orion's belt. Its coherent structure and 7-kilometer-per-second expansion velocity lead astronomers to conclude that the shell is being driven by a burst of star formation that occurred 2 or 3 million years ago.

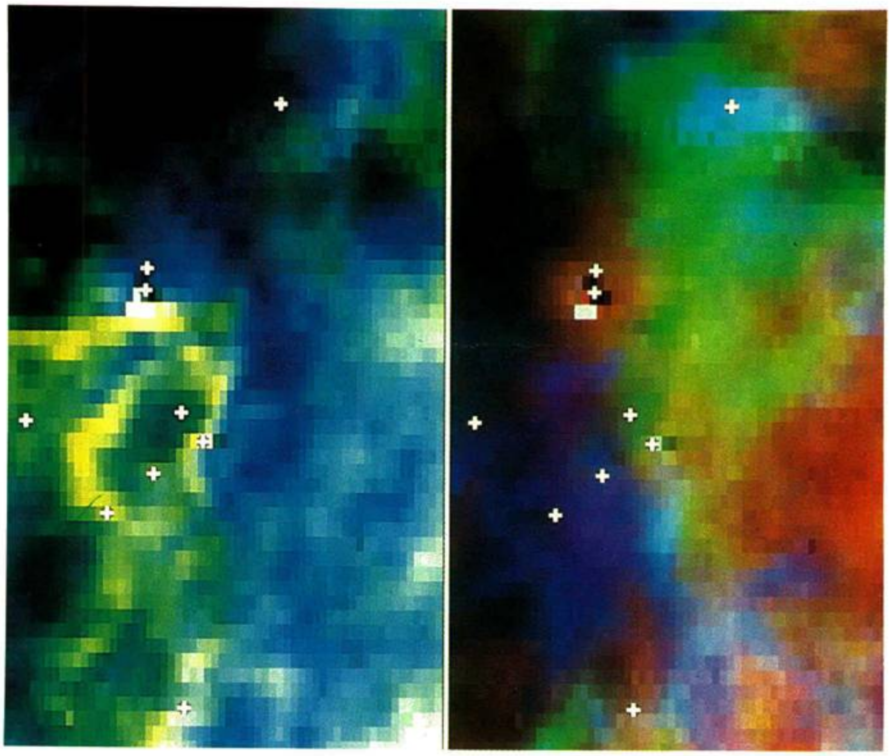
The discovery was announced at the January meeting of the American Astronomical Society in Arlington, Virginia, by Bruce Elmegreen of the IBM Thomas J. Watson Research Center in Yorktown Heights, New York, Debra Elmegreen of Vassar College Observatory, and Frederick Chromey of IBM and Vassar College Observatory. The shell emerged on a huge sky map the astronomers assembled based on 5,000 spectra of the Orion region taken at a wavelength of 21 centimeters. The astronomers made the observations with the 140-foot radio telescope at the National Radio Astronomy Observatory in Green Bank, West Virginia, and processed the resulting data using a supercomputer at the T. J. Watson Research Center.

"We taught the computer to compare spectra from neighboring points on the sky, looking for and sorting out local blends of different clouds with a rationale similar to that used by our own eyes and brains," Chromey said.

The locations, densities, and velocities of over twenty clouds and filaments were determined. In addition to the gaseous shell the astronomers found clumpy structures of gas throughout the region. They also mapped a giant "atmosphere" of low-density gas that surrounds the molecular cloud in which new stars are forming.

The molecular cloud is known to contain a large number of intermediate- and low-mass stars and at least one cluster, evidence that stars are thriving in the cloud. The weight of the hydrogen atmosphere around the main cloud is so great that the molecular material beneath it is squeezed to ten times the normal pressure in the Galaxy, said Bruce Elmegreen. This well-defined pressure boundary in effect acts like a cocoon in which young stars can form free of disturbances in the Galaxy.

"This high pressure protects all but the edge of the cloud from the shock waves of stray supernova explosions and destructive ultraviolet radiation," said Elmegreen, "allowing most of the new stars inside the cloud to be born in peace."



**A SHELL OF HYDROGEN GAS**, the result of an earlier burst of star formation, expands through Orion's belt (right). The shell and other gas clouds are located within a hydrogen atmosphere (color-coded light blue to yellow, left image). Courtesy of Bruce Elmegreen of IBM, and Frederick Chromey and Debra Elmegreen, Vassar College Observatory.

## BACKGROUND GALAXIES REVEAL DARK MATTER

Astronomers have found gravitational distortions in a field of distant galaxies that are apparently caused by massive clumps of intervening dark matter. The distortions, which make galaxy images look like arcs, allow astronomers to "see" dark matter for the first time.

J. Anthony Tyson and Richard Wenk of AT&T Bell Laboratories and Francisco Valdes of the National Optical Astronomy Observatories reported their findings in the January 20 issue of the *Astrophysical Journal Letters.* Ultra-faint imaging techniques were used to detect the very faint screen of background galaxies. The observations were then processed using software developed by the team that automatically detects distortions in the galaxy images.

In the last few years super-sensitive charge-coupled devices have revealed the presence of a veil of faint, blue galaxies over 10 billion light-years away. (See "Galaxies at the Confusion Limit," December 1988.) At the faint limits of the detectors the sky appears covered with these galaxies. Astronomers estimate that there are over 200,000 galaxies per square degree brighter than magnitude 27, which is 300 million times fainter than the faintest star visible to the unaided eye.

Tyson believes this backdrop of galaxies can be used as a tool to look for dark matter lying along the same line of sight. Light from the distant galaxies is gravitationally bent around intervening galaxy clusters, stretching the background galaxy images into arcs. The

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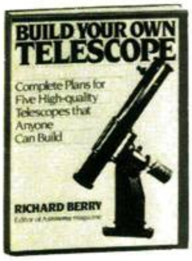
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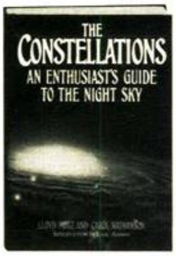
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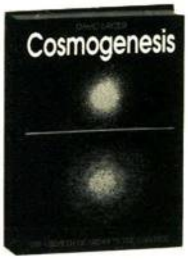
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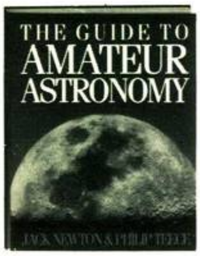
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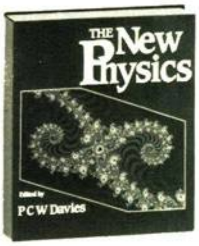
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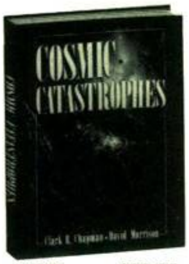
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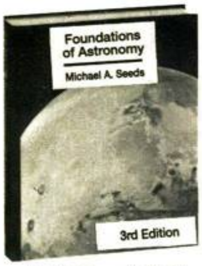
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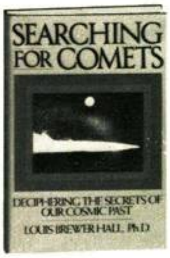
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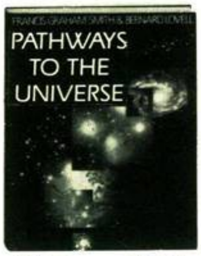
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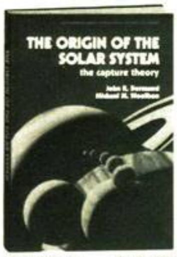
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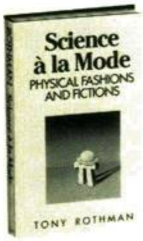
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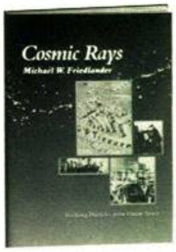
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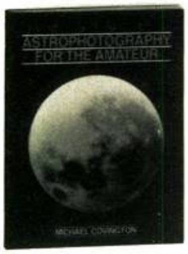
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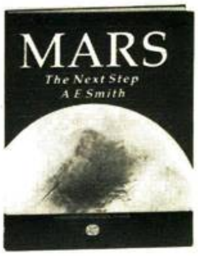
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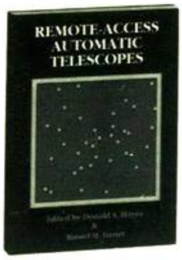
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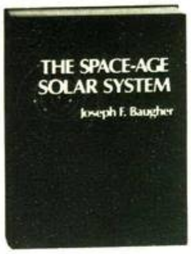
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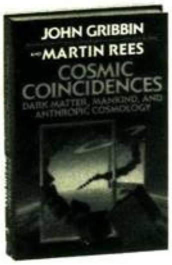
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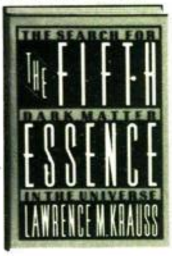
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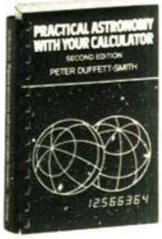
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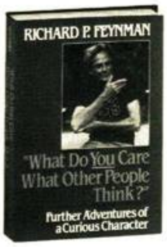
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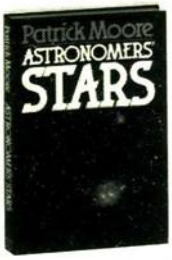
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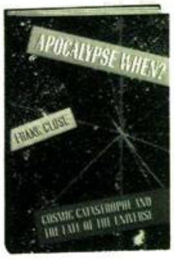
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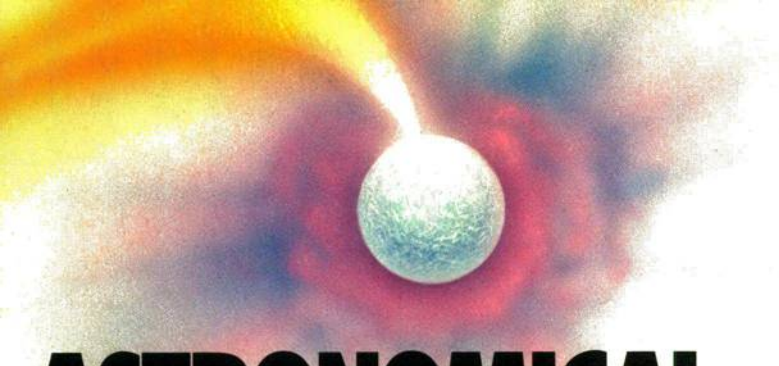


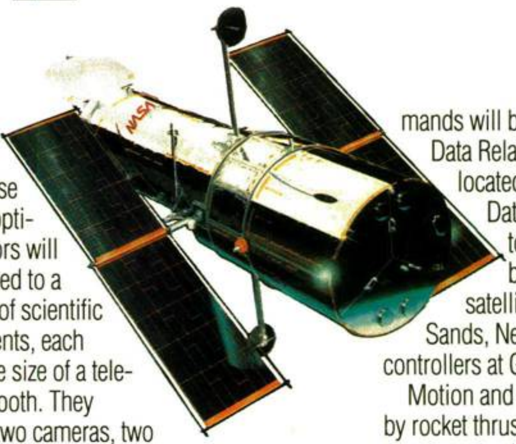
# ASTRONOMICAL GALILEO.

The massive gravitational pull of a white dwarf sucks matter from a red supergiant. Matter torn from the red star is funnelled to one of the dwarf's magnetic poles, heating electrons, which collide with ions to release powerful x-ray photons. This stellar encounter will last millions of years, resulting eventually in the red star's demise. The universe abounds with incredible phenomena like this. Soon, the Hubble Space Telescope will bring these spectacular scenes into sharp focus.

Launched by NASA in spring 1990, the Hubble Space Telescope could well be the greatest scientific achievement of the 20th century. It will probe the universe as it existed 14 billion light-years ago. Lockheed, the systems integrator for this magnificent technological feat, will control the Hubble Space Telescope as astronomers seek to unravel the mysteries of galactic origin, evolution and dynamics.

The Hubble is a conventional reflecting telescope much like the instruments found in mountaintop observatories. Its optics comprise an eight-foot-diameter primary mirror and a 12-inch secondary mirror. The primary mirror, an 1,800-pound concave hyperboloid, is made of fused silica glass to prevent thermal distortion. It took 28 months of painstaking work to grind and polish the mirror's surface. If the Earth's surface were as smooth as the polished mirror, Mt. Everest would be about five inches high.

Even the most powerful ground-based telescopes are hindered by atmospheric turbulence. For astronomers, it's like peering at the surface of a deep, murky lake while standing on the bottom. The Hubble Space Telescope will orbit 380 miles above the Earth, beyond the distorting effects of its atmosphere. With this unobscured view, the space telescope will capture extraordinarily precise stellar images. Its spatial resolution will approach 0.1 arc second, 10 times more accurate than any terrestrial instrument.



Light reflected from these superb optical mirrors will be directed to a number of scientific instruments, each about the size of a telephone booth. They include two cameras, two spectrographs and a high-speed photometer. A wide-field and planetary camera will generate spectacular pictures of supernovae and planetary atmospheres. A faint-object camera will intensify the light it receives by 100,000 times, exposing stars of 28th magnitude, objects so distant no ground telescope has ever seen them.

The space telescope's high-resolution and faint-object spectrographs gather electromagnetic radiation and disperse it over the spectrum. The careful analysis of stellar spectra enables astronomers to learn more about a star's chemical composition, its rotational velocity and the strength of its magnetic field. These instruments may uncover the mysterious properties of quasars—powerful energy sources that outshine entire galaxies.

To determine the exact distance and nature of exotic stellar bodies like quasars and black holes, the Hubble Space Telescope will carry a high-speed photometer. This extremely sensitive instrument measures the intensity and frequency variations of light and will be able to distinguish events separated in time by only 10 microseconds.

Through periodic servicing by space shuttle crews, the telescope's planned life is 15 years. As new technologies emerge, the Hubble's modular instruments will be replaced on orbit by shuttle astronauts.

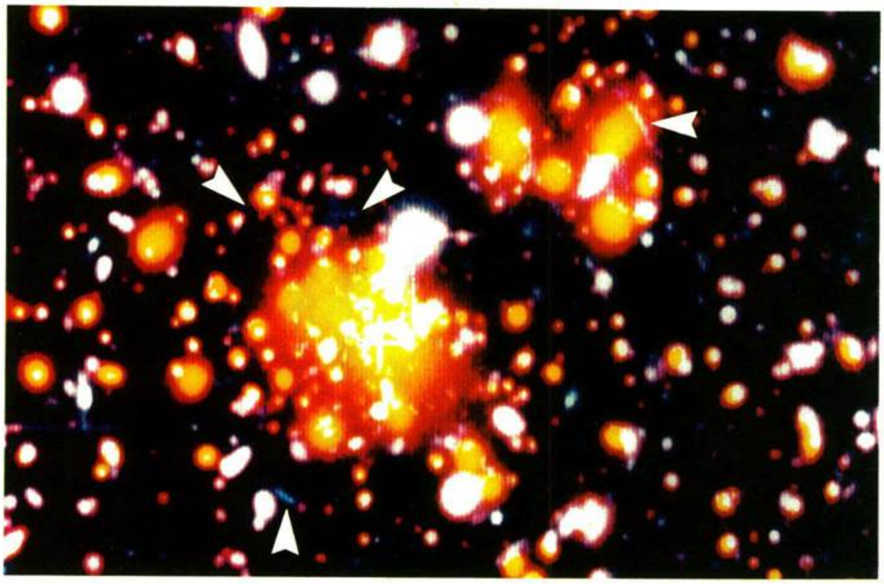
Lockheed technicians will guide the Hubble Space Telescope from NASA's Goddard Space Telescope Operations Control Center. Commands will be sent through the Tracking and Data Relay Satellite System, which is located 22,000 miles above the Earth. Data gathered by the telescope, up to 400 million bytes a day, will be downlinked from the TDRSS satellites to a ground station at White Sands, New Mexico, and then directed to controllers at Goddard.

Motion and stability will be controlled not by rocket thrusters but by an ingenious set of reaction wheels. These wheels will transfer momentum throughout the telescope, enabling it to accelerate, coast and decelerate to varying positions. The telescope's remarkable pointing system, designed by Lockheed, will yield stability of 0.007 arc second. This feat is equivalent to focusing on a dime in Los Angeles while standing on a carousel in San Francisco—of course, the carousel happens to be rotating at 17,000 miles per hour.

As the primary systems integrator for the Hubble Space Telescope program, Lockheed has conducted exhaustive analyses of all the telescope's systems. Along with NASA, Lockheed has coordinated the work of more than 350 organizations. It's been a massive undertaking, but one which will surely lead to stunning scientific revelations.

For the first time, mankind will have an unimpaired window on the universe. Who knows what fantastic discoveries lie ahead? The clues are in the stars themselves. The Milky Way alone contains 200 billion stellar bodies; and it's just one of 10 billion galaxies—galaxies that we know exist. The Hubble Space Telescope may lead astronomers to new galaxies, new solar systems. Perhaps, somewhere beyond the shattering cataclysm of supernovae and violent red supergiants, there exists a planet similar to our own. With the Hubble Space Telescope exploring the infinite vistas of the universe, anything is possible.

**Lockheed**
Giving shape to imagination.



**FAINT BLUE GALAXIES** are gravitationally distorted into miniarcs centered around the intervening galaxy cluster Abell 1689 (red-yellow). Arrows point to some of the blue galaxy arcs. Photo courtesy of J. Anthony Tyson and Richard Wenk, of AT&T Bell, and Francisco Valdes, of National Optical Astronomy Observatories.

amount of stretching depends on the total mass of the interposed cluster. Astronomers suspect that most of the mass associated with galaxy clusters is nonluminous. Indeed, in recent years many stretched images of background galaxies have been found partially encircling rich foreground galaxy clusters.

Using a charge-coupled device and the 4-meter Cerro Tololo Inter-American Observatory Telescope in La Serena, Chile, as well as the 3.6-meter Canada-France-Hawaii Telescope on Mauna Kea, Tyson and his colleagues imaged the regions around two galaxy clusters and found evidence for gravitational lensing in both.

In one region centered on the compact galaxy cluster Abell 1689, the astronomers found about thirty gravitationally lensed background galaxies within the central square arcminute of the cluster. Many of the stretched galaxy images, some several arcseconds in apparent length, were revealed when the galaxy cluster was subtracted from the image.

Tyson believes that if large samples of the sky can be surveyed for similar distortions of background galaxies, it may be possible to directly measure the dark-matter distribution in galaxy clusters. Knowing how and where dark matter clumps together could help delineate the nature of dark matter in the universe.

## *TELESCOPE MAKERS ASSOCIATION FORMED*

Representatives of telescope manufacturing firms and the astronomical press met February 10 in Flagstaff, Arizona, to discuss the formation of a telescope industry association. The purpose of the association, called the Telescope Optics Manufacturers Association (TOMA), is to set quality standards for astronomical telescopes.

According to organizer Paul Jones, TOMA would also educate telescope buyers, standardize optical quality claims made in the advertising of TOMA members, and build consumer confidence in astronomical telescopes. Jones is the owner-optician of Star Instruments, a telescope manufacturer in Flagstaff. Celestron International, Edmund Scientific Company, Meade Instruments Corporation, Morvac Optical Coating, and Star Instruments have participated in the two organizational meetings of TOMA, the first of which was held in January.

TOMA is concerned that in today's mass market the lack of industry standards for astronomical optics may have harmed the astronomy hobby market. The association is seen as a way to bolster consumer confidence.

TOMA member firms agreed at their meeting that telescopes sold as astronomical instruments would meet three basic criteria: they would form good star images, be free of astigmatism, and produce straight bands when tested with an appropriate Ronchi grating. Behind these guarantees to the consumer would lie advisory technical standards yet to be established. TOMA members agreed that these standards would not be tied to any particular method of testing or testing technology that would place TOMA membership beyond the means of small manufacturers.

"At this point we have a good number of companies in the industry that are committed to joining TOMA," said Jones. "We hope to involve even more companies at future TOMA meetings." TOMA will meet again this spring, possibly at the Riverside Telescope Makers Conference held at Big Bear, California, to elect officers and establish bylaws.

## Space News

# AN ALL-TERRAIN MARS CAR

"To boldly go where no man has gone before" might easily be the motto of NASA's Mars Rover project. Before astronauts step onto the surface of Mars, unmanned robotic roving vehicles will have scouted out the terrain, found suitable locations for base camps, and generally made sure that things are safe for humans. After people make landfall, rovers will be enlisted to carry astronauts around as they explore the Martian territory.

NASA has received the results of three studies of Mars rover technology, explained Donna Pivirotto, manager of Mars Rover studies at the Jet Propulsion Laboratory. Each study resulted in a distinctly different vehicle each about the size of a small car. The most complex rover is a three-bodied transport devised by FMC Corporation of San Jose, California. Each body has a pair of wheels with its own independent power system. If the front set of wheels falls into a dust pit, for example, the other wheels can pull the vehicle out.

This vehicle can also right itself if it tips over.

Martin Marietta came up with a simple walker with two bodies. Each body has its own set of tripod legs. When one set of legs is firmly on the ground, the other tripod lifts up, moves forward, and sets on the ground. By repeating this process the vehicle moves forward, something like an "inchworm," Pivirotto said.

The simplest of the designs came out of JPL. This is a single-bodied vehicle with six wheels. The wheels are mounted on "bogey levers," which allow the body to remain stable even when the vehicle is traveling over rough ground.

Pivirotto said the rovers will probably be powered by radioisotope thermoelectric generators (RTGs), small nuclear power supplies similar to the ones used on *Voyager, Pioneer,* and *Galileo.* "We looked at solar power for the rovers, but its not very efficient and the vehicles would have to sit still at night because they couldn't carry enough batteries," Pivirotto said.

These designs gave the space agency a good idea of the types of technology that can go into a rover. The next step is to "understand the real requirements," Pivirotto said. In other words, NASA needs to learn just what people want rovers to do on Mars. For example, do scientists want a vehicle that travels long distances? Do they want it to collect lots of rock samples, or are they more interested in vehicles that can make stereo images of the terrain? This year NASA is implementing a program to answer questions like these.

One of the issues yet to be worked out is how the unmanned rovers will navigate over the Martian terrain. "We have come up with two classes of concepts," Pivirotto said, "human supervised and semi-autonomous." With human supervised, the rover sends an image to Earth where scientists decide in detail the next leg of the journey. The commands are then sent to the rover. Because it takes from 5 to 20 minutes for radio signals to travel between Earth and Mars, this approach makes for slow travel. With the semi-autonomous mode, scientists on Earth instruct the rover to travel to a point, for example, one mile away. "It's the rover's job," Pivirotto said, "to figure out the safest or most energy-efficient path." Though this will make for faster travel, it will also require the development of advanced — and expensive — computer hardware and software. — *Robert G. Nichols*

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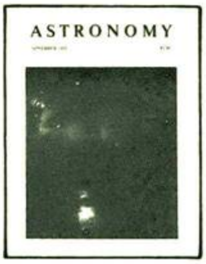

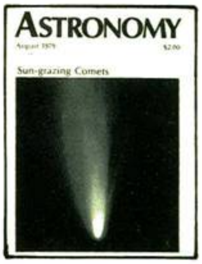

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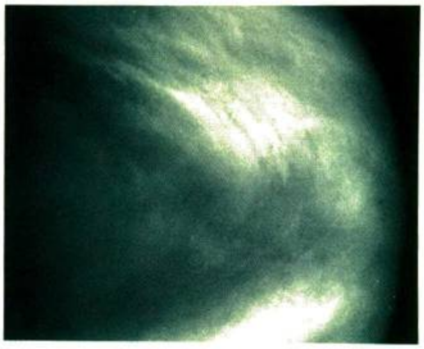


**A NEW PHOTO** of the Venutian cloudtops was taken on February 12 by *Galileo*'s camera, using a violet filter, when the spacecraft was one million miles from Venus.

## *GALILEO SPEEDS UP AFTER VENUS FLYBY*

Four months into its circuitous six-year journey to Jupiter, the *Galileo* spacecraft flew by Venus on February 9 and in the process boosted its cruising speed by 5,000 miles per hour. *Galileo* also scanned the day and night sides of Venus with several of its instruments as it flew by the planet at over 80,000 miles per hour.

The camera onboard *Galileo* temporarily went haywire during the Venus flyby. For almost five hours the camera's shutter snapped open and closed twice a minute, apparently due to faulty computer commands. The malfunction was quickly corrected and *Galileo* successfully took more pictures of Venus as it sped away from the planet.

The flyby was the first of three "gravity-assist" maneuvers designed to get *Galileo* to Jupiter by December 1995. The next assist is scheduled for December 8 when the spacecraft will make a 600-mile flyby of Earth.

## *NASA REARRANGES SHUTTLE LINE-UP*

NASA announced a new space shuttle launch schedule that still includes nine launches in 1990 despite a series of minor delays in recent missions.

The *Hubble Space Telescope* launch has slipped three weeks to April 18 and the following mission, the *Astro-1* payload of ultraviolet and x-ray telescopes, has moved back two weeks to May 9. The *Ulysses* mission kept its launch date of October 5.

The mission experiencing the biggest delay is the *Gamma-Ray Observatory*, the second of NASA's four "Great Observatories," which was rescheduled to November 11 from June 4.

## *Amateur News*

# *STARS SHINE ON WINTER STAR PARTY*

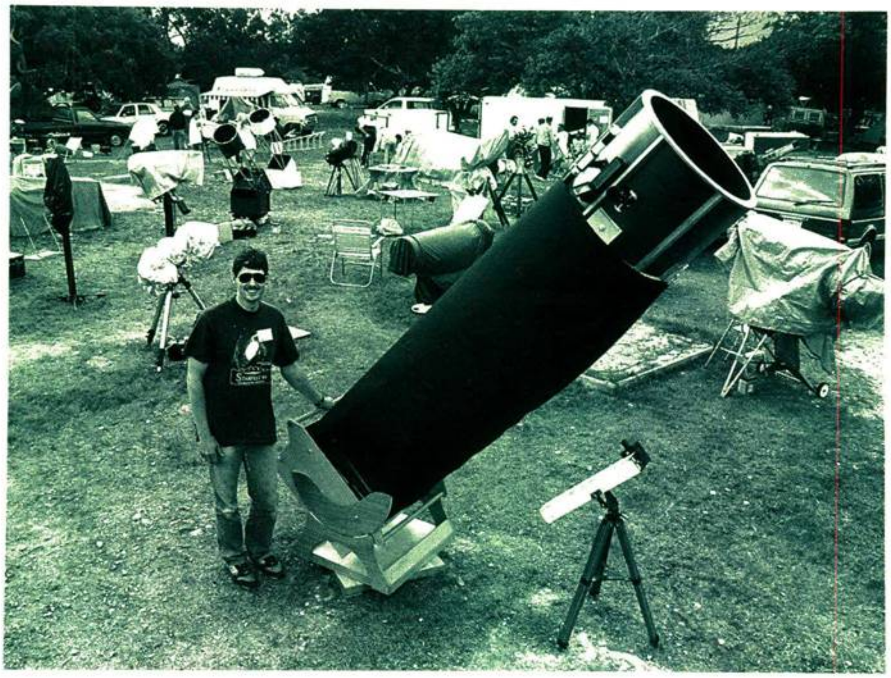
The first amateur astronomy meeting of the 1990s drew a capacity crowd of 362 observers and telescope builders. Astronomers convened for the sixth annual Winter Star Party from January 25 to 28 at a Boy Scout camp on Spanish Harbor Key, approximately 125 miles south of Miami. The Winter Star Party site is the southernmost dark-sky site in the continental United States and as such offers unparalleled views of Omega Centauri, Eta Carinae, and other southern deep-sky attractions.

The focus of this year's star party was observing from dusk 'til dawn, with Jupiter serving as one of the prime attractions. Dozens of large-aperture telescopes were trained on the giant planet, revealing awesome detail in the equatorial and northern belts and zones. Although the South Equatorial Belt had faded to a pale cream shade, the Great Red Spot was a healthy pink and clearly visible. The spectacular passage of Io's shadow just south of the Great Red Spot on Saturday evening kept observers talking the next day.

Daytime activities included talks by planetary astrophotographer Don Parker, CCD imager Bob Higgins, *1000+* author Tom Lorenzin, and ASTRONOMY and *Telescope Making* editor Richard Berry, as well as swimming, snorkeling, sunbathing, and walking the nature trails on nearby keys. Two Dobsonians of 25-inch aperture were on display, seven of 20-inch aperture, and at least a dozen 17.5- or 18-inch telescopes were in operation.

According to organizer Tippy D'Auria, the site was entirely filled this year and many potential registrants had to be turned away. Telescopes, tents, and vehicles occupied virtually every foot of the campground. Although there are plans to obtain more space by leasing an adjacent Girl Scout camp in 1991, this camp may not be available and space would again be limited.

The Winter Star Party is sponsored by the Southern Cross Astronomical Society of Miami, Florida. A report on telescopes shown at the Winter Star Party will appear in *Telescope Making #40*. □



**THE LARGE AND THE SMALL** mixed at the 1990 Winter Star Party. Charles Ferguson poses with a 20-inch Dobsonian and a 2-inch solar telescope.

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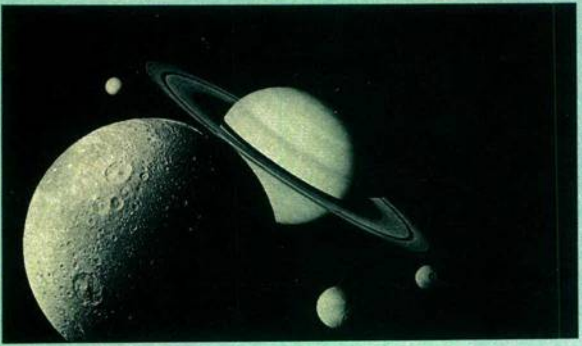

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Co-founders of The Planetary Society: Bruce Murray, Professor of Planetary Sciences, California Institute of Technology (seated left); Carl Sagan, Director, Laboratory for Planetary Studies, Cornell University (seated right); Louis Friedman, Executive Director (standing).

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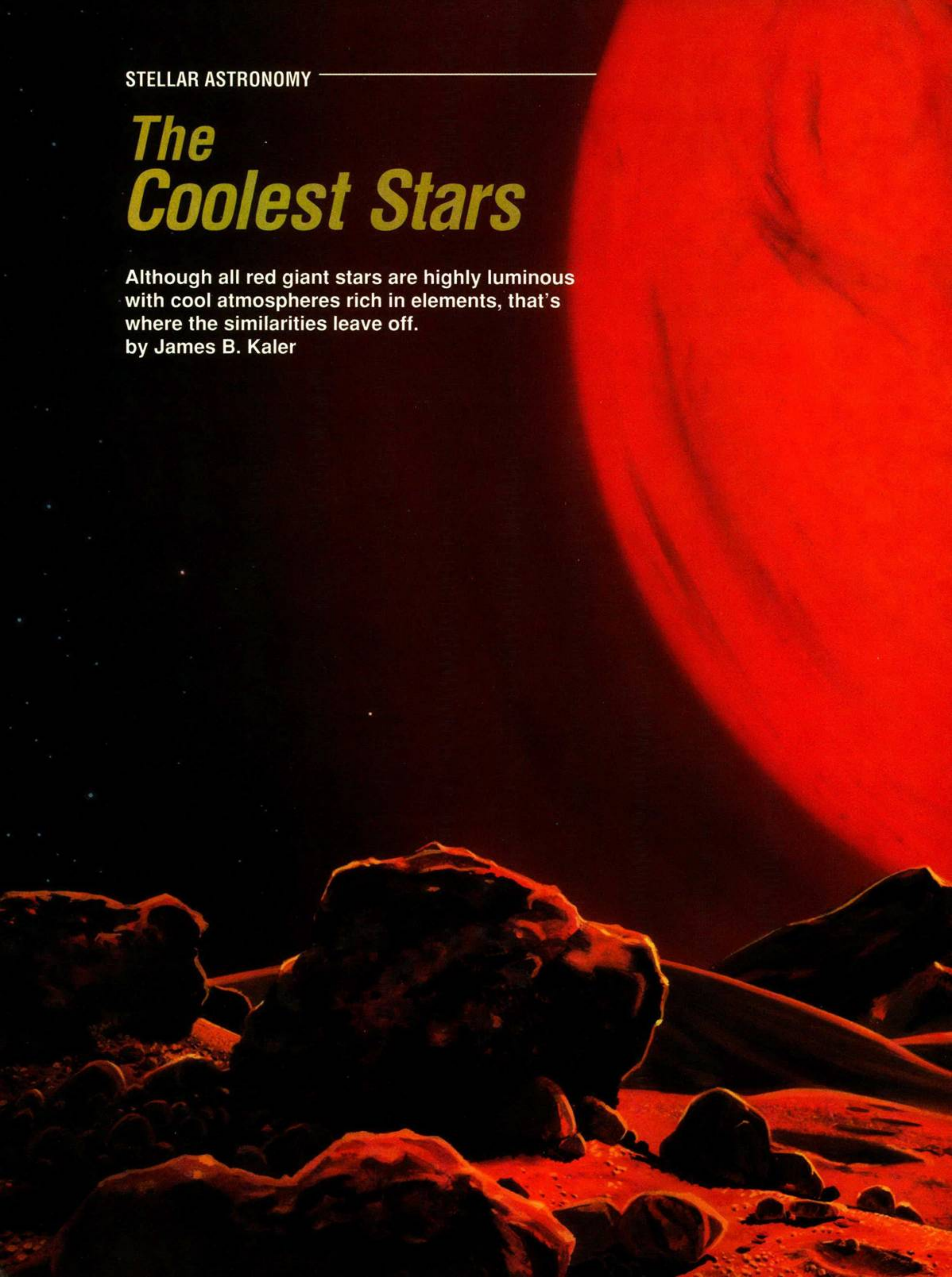
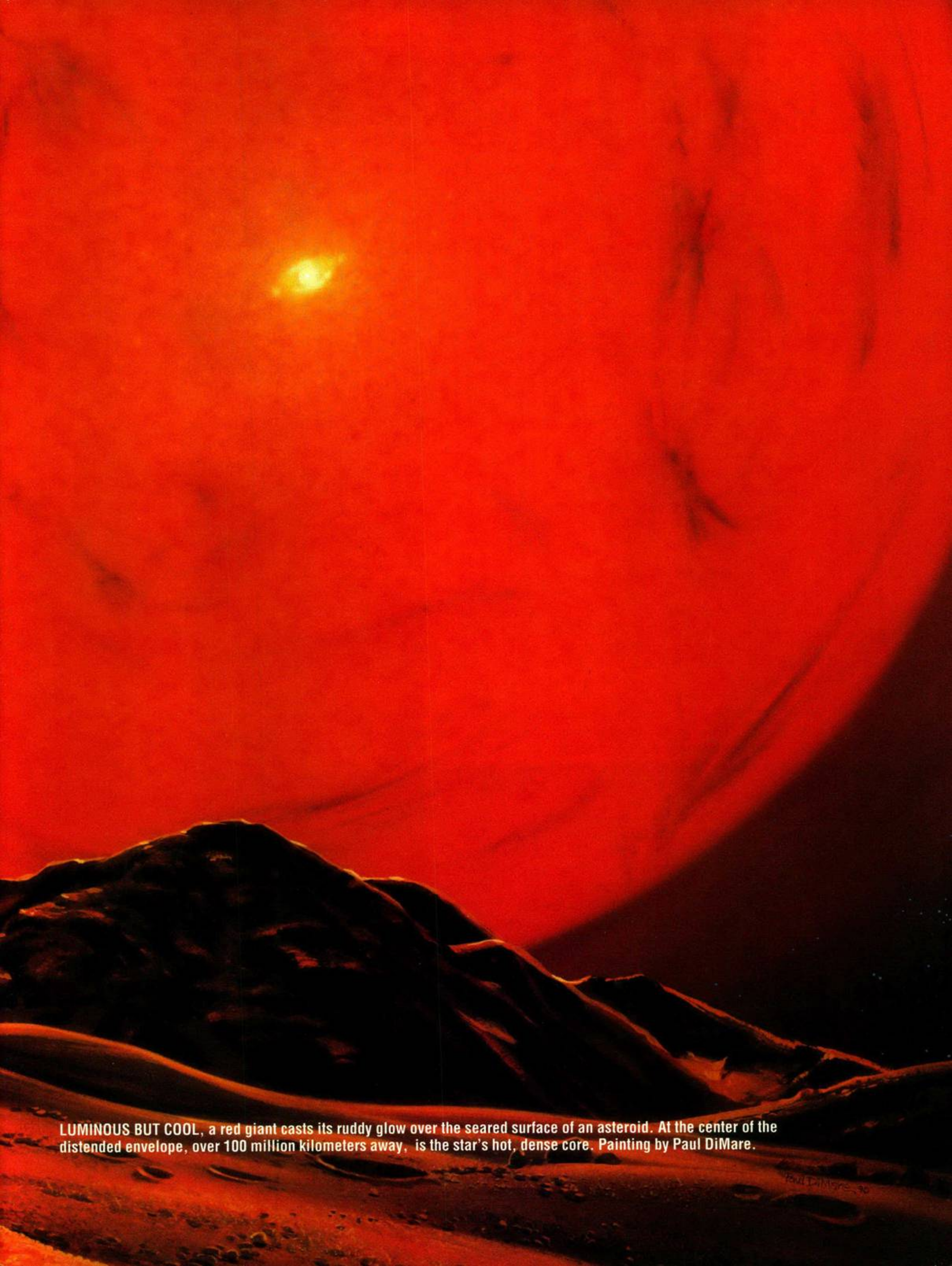
STELLAR ASTRONOMY

# The Coolest Stars

Although all red giant stars are highly luminous with cool atmospheres rich in elements, that's where the similarities leave off.

by James B. Kaler





LUMINOUS BUT COOL, a red giant casts its ruddy glow over the seared surface of an asteroid. At the center of the distended envelope, over 100 million kilometers away, is the star's hot, dense core. Painting by Paul DiMare.

On a clear, moonless night out in the country the stars seem to shine with an intensity they don't have in town. The eye tends to wander over the celestial vault in an effort to take in all the stars at once. Yet if you examine the individual stars more closely, you'll notice that they are distinguished not only by their different brightnesses but by their colors as well. Many of the hues are subtle: some are white, others are tinged with blue, and still others yellow.

But here and there, standing out from all the others, are the orange and red ones that give so much character to the nightly display. This group includes many favorites: orange-colored Arcturus, now well above the eastern horizon by nightfall; reddish Antares of summer; Aldebaran of autumn; and Betelgeuse of winter. Others include Dubhe, the star in the lip of the Big Dipper's bowl; Kochab positioned similarly in the Little Dipper, Beta Andromedae; and a few stars in the Hyades.

These reddish stars are only a sampling of a remarkable class that ranges in brightness from a million times the Sun's luminosity to nearly a millionth, an astonishing drop of almost a million, million times from brightest to dimmest. Furthermore, these stars are in diverse states of evolution. Beta Andromedae, for example, shines with a steady light, but others, like Mira, vary widely in brightness over periods of a year or more. And still other dim ones flare up within minutes like fireflies in space.

One thing these stars all have in common is that they are cool. Even the brightest members of this class have surface temperatures far below that of our 6000-kelvin Sun; many are in the 2000-kelvin range. These low temperatures are significant because they provide the perfect environment for the formation of substances not found in hotter stars — complex molecules. (The heat energy in hotter stars keeps atoms too stirred up to bind together into molecules.) Astronomers want to understand what the rich compositions of these stars reveal about their natures, how the various members of the coolest classes are physically related, and what role cool stars play in the grander scheme of stellar evolution.

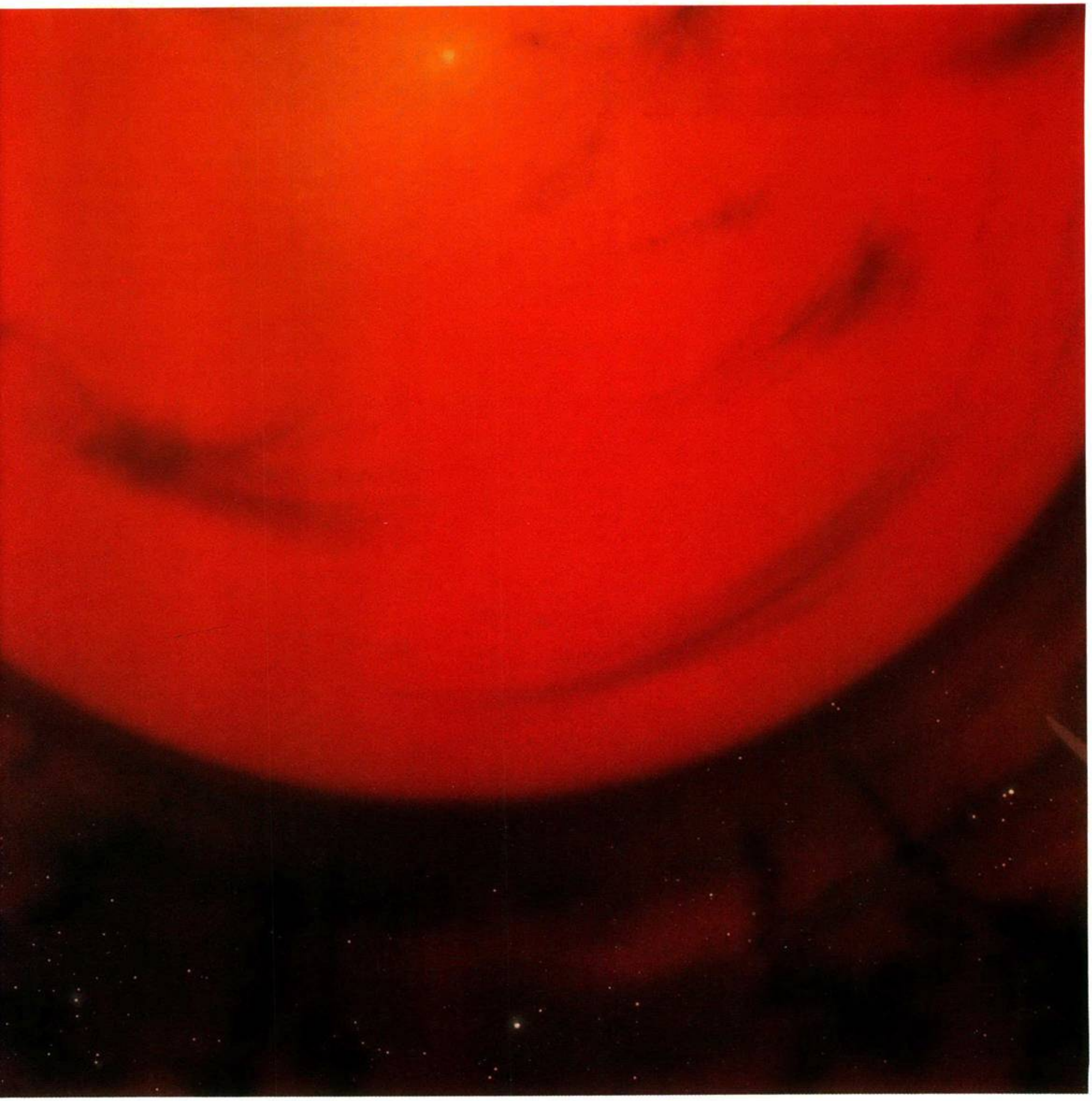
To begin to understand the coolest stars, astronomers must plumb the tenuous stellar atmospheres to learn about their chemical makeup and evolution. One of the best places to begin is by plotting the star's lifeline on the Hertzsprung-Russell diagram. This important tool, developed independently in the early part of the century by Danish astronomer Ejnar Hertzsprung and American astronomer Henry Norris Russell, locates stars on a graph according to their luminosities and surface temperatures. The H-R diagram allows astronomers to see how stars are born, live, and die.

### Decoding Spectral Lines

The diagram plots luminosity, in the form of absolute visual magnitude (the apparent brightness a star would have if it were only 32.6 light-years away) against spectral class, which is an indicator of surface temperature. Nearly all stars are assigned to one of seven spectral types: O, B, A, F, G, K, or M. Temperatures range from 50,000 kelvins in type O, through 9000 kelvins at A, 6000 kelvins at G, to 3000 kelvins and below in type M.

Because the coolest stars are rich in molecular compounds, their spectra are enormously complex. One of the astronomer's most imposing tasks is matching the intricate spectral features with known elements and molecules.

All starlight is a mixture of colors — the spectrum. Detectors on the ground and in space have shown us that stars also radiate in the infrared (wavelengths longer than red) and ultraviolet (shorter than violet). Starlight is created deep in the stellar core as high-energy gamma rays by thermonuclear fusion. As this light finally escapes from the star it passes through the thin, cooler outer atmosphere. Here atoms and ions (atoms with one or more electrons removed) in the gas



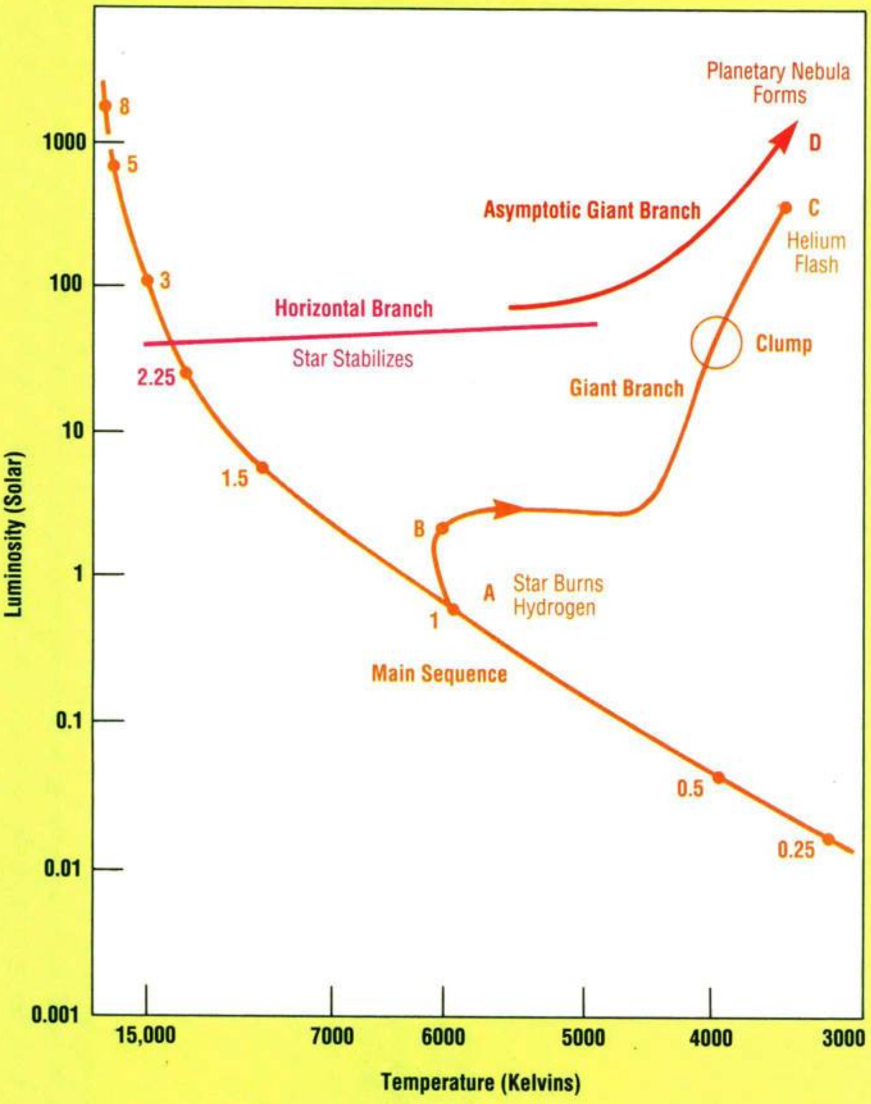
**A RED GIANT PUFFS UP** during a thermal pulse. At this stage the star is blowing off dust and gas. Eventually the exposed hot core will ionize the gas, forming a planetary nebula. Painting by Paul DiMare.

absorb specific wavelengths of light, thus implanting their signatures on the outflowing rays.

Zooming in on the structure of the atom for a moment, we can better see how this is accomplished. Absorption is performed by electrons that are bound to the atoms or ions. Electrons can only exist in certain orbits or energy states that are peculiar to each atomic species. An electron jumps from a lower to a higher orbit when it absorbs a ray of light (a photon) that has an energy exactly equal to the energy difference between the orbits. When this happens, energy of a specific color is removed from the star's continuous energy distribution of light. The result is a narrow, dark gap in the continuous spectrum — an absorption line.

Each type of atom or ion has a large number of possible orbits associated with it. Therefore it can produce a multitude of absorption lines in a unique pattern. A cool star's spectrum can exhibit hundreds or even thousands of these absorption lines, which are

## Lifeline of a Giant



**In ten billion years of fusing hydrogen on the main sequence, a sunlike star evolves only from A to B. When the hydrogen is used up the star "moves" upward and becomes a giant. At C, the helium core ignites and the star stabilizes on the horizontal branch. Stars with solar compositions tend to clump at far right. When the helium core is spent the star climbs the asymptotic giant branch, losing mass as it goes. Near D it produces a planetary nebula.**

produced by the mixture of all the kinds of atoms and ions in its atmosphere. Astronomers can tell what kinds of atoms are in the gas by measuring the positions, or wavelengths, of these myriad lines and comparing them with the lines in laboratory spectra. And by measuring the strengths of the absorption lines (the amount of energy or light actually removed from the spectrum), the star's temperature, density, and chemical composition can also be derived.

All the basic kinds of stellar spectra are produced by stars with about the same compositions. But not all stars have the same temperature. More importantly, spectral lines have widely different line strengths in stars of different temperatures. It is this relationship that allows astronomers to classify stars.

Take hydrogen, for example. The lines in the optical spectrum arise when an electron jumps from the second orbit in the hydrogen atom. But the gas must be at the right temperature before the electrons can be lifted into this orbit by collisions between atoms. That temperature is fairly high, because we see hydrogen lines best in hotter stars, with their strongest ones observed at type A near 10,000 kelvins. As temperature drops, however, fewer electrons are driven to the second orbit and these lines rapidly weaken. At the cool type M stars they are effectively gone. In types O and B, which are hotter than A, the hydrogen becomes ionized. The atoms lose the light-absorbing electrons and the lines again weaken. The spectra of all the different atoms and ions behave in this way. Each has a particular temperature at which its absorption line is strongest, and at higher or perhaps lower values it weakens and even disappears.

### The Making of a Giant

Temperature is not the only criterion involved in stellar classification. Consider the M stars in the H-R diagram. The luminosity of a square centimeter of stellar surface depends only on temperature (actually the 4th power of it!). A star's total luminosity, however, depends on temperature and size. The higher a star goes in the H-R diagram at a given temperature, the bigger and more luminous it must be. In order for Beta Andromedae to be 1,600 times brighter than Eta Cassiopeiae B, it must be 40 times larger.

But how do giant stars get to be big, bright, *and* cool? The answer lies in the theory of stellar evolution. Roughly 90 percent of all the stars we see occupy the main sequence of the H-R diagram. A star remains on the main sequence for the majority of its life while it "burns" its quota of hydrogen into helium in the core (the outer envelope and the atmosphere are not much affected). When the fuel is used up, the nuclear fire goes out, the core contracts under gravity, and the star begins to evolve. After concluding their main-sequence lifetimes, stars can go in a number of evolutionary directions, depending almost entirely on their initial masses. Giants are produced by stars between 1 and 8 solar masses.

As the core contracts and heats, a shell of burning hydrogen works its way outward, expanding the star's atmosphere to enormous proportions, and a giant is born. Expansion has two consequences: the star becomes cooler at the surface and, because it is so much larger, it actually becomes more luminous. This expansion phase halts when the helium core becomes so hot that it explosively ignites and begins to fuse to carbon. This event is called the helium flash.

On this ascent of the giant branch a star has a temperature of around 3300 kelvins, and just before the helium flash a star like the Sun will reach a luminosity some two hundred times solar. To be that bright at such a low temperature requires a radius forty times that of our home star. In the Sun's place, such a star would stretch half way to Mercury and would take well over an hour just to rise in the morning.

After the helium flash the star shrinks in size, and as helium burning stabilizes it falls to the "clump" about halfway down the evolutionary track; those with low metal contents can spread out to the left along a horizontal branch. Eventually though, the helium fuel in the core runs out and the central zones of the star again begin to contract, triggering a helium-burning zone around the core. Once again the star swells into a giant, but this time it follows a slightly different evolutionary path up the H-R diagram that astronomers call the asymptotic giant branch (AGB).

Now the star consists of a dead carbon core surrounded by a helium-burning shell that is itself encased in a hydrogen-burning shell. As it ascends the AGB the helium shell dies and the star cycles into hydrogen burning, which feeds helium into the quiet shell below. About halfway up the AGB the quiet but growing helium shell suddenly and explosively comes to life. This sudden burst of energy drives the hydrogen-burning shell outward and cools it, effectively turning it off. Ultimately, the helium burning dies away and the hydrogen shell contracts, heats, and re-ignites again. These helium flashes, or thermal pulses, continue with increasing frequency and violence as the star ascends the AGB.

These AGB stars become more luminous and cooler than many giants, and can frequently grow much larger. Spectral classes plummet to M8 and the temperatures to 2500 kelvins or so. Mira, an archetype AGB star, is over 200 times larger than the Sun and approaches the orbit of Mars in size.

As the star grows it loses mass through a powerful wind. Eventually the outer layers are stripped away, exposing the core and halting the thermal pulses. The ejected, expanding envelope is destined to become a planetary nebula, lit by the star's core, which will be its nucleus. (See "Realm of the Hottest Stars," February 1990.) All of these evolutionary changes happen with remarkable speed. From the time a star like the Sun departs the main sequence to become a giant until it begins to form a planetary nebula occupies only a billion years or so.

### Cold Temperatures, Odd Compositions

The fascinating natures of the giant stars go beyond their size. To understand what is happening with them we must delve into their hearts and souls, through their spectra. Look at the features of the M spectra on page 28. Instead of narrow absorption lines, we see *bands* with one sharp and one diffuse edge. These are the signatures of molecules that form in the cool atmospheres of giant stars. Most of the obvious bands in Mira's spectrum are produced by titanium oxide (TiO). Molecules are easily broken apart at higher temperatures, but TiO is fairly hardy; it is found in stars as hot as 4200 kelvins. Several other molecules — vanadium oxide (VO), magnesium hydride (MgH), and even molecular hydrogen ($H_2$) develop at cooler temperatures.

As mentioned earlier the spectra of cool stars are enormously complex due to the numerous molecular lines. The ability of a molecule to vibrate and rotate causes electronic absorption spectra to split and broaden into a whole series of bands, each one containing dozens of individual lines. A cool M star may have a million or more discrete absorption features! As the temperature drops from 3600 kelvins (type M0) to about 2600 kelvins (M8), more and more molecules form and the absorption bands deepen until the entire spectrum is nearly eliminated. This "forest" of absorption lines makes it very difficult to measure the temperatures of these stars.

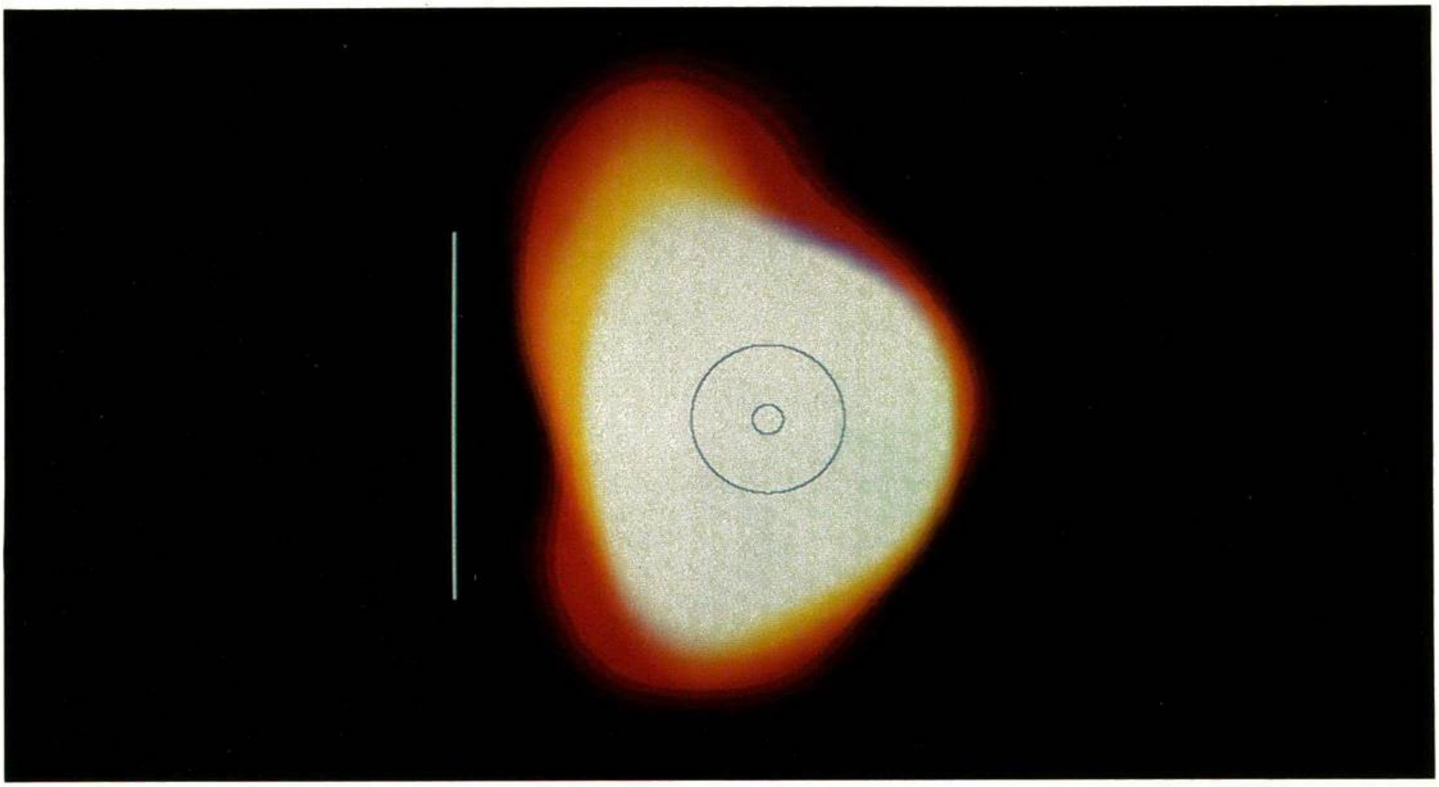
### Carbon Stars

Now comes a startling surprise. Sprinkled here and there over the sky are a few dim, deep red stars that are far more strongly colored than Betelgeuse or Mira. Casual skywatchers are unaware of them because even the brightest is only 5th magnitude. These rubylike stars clearly have low temperatures like those of class M, but their spectra are totally different. The bands fade in the direction *opposite* to those of M stars. They are not caused by metallic oxides but are produced instead by molecules of carbon, notably diatomic carbon ($C_2$) and cyanogen (CN). These are carbon stars. Some carbon stars are warmer than class M (up to class K), where they are called R stars. Others have temperatures cooler than class M, where they are referred to as class N. Collectively, R and N classes are referred to as type C (for carbon).

The deep red color of the cooler N-type carbon stars is the result of an enormous amount of absorption by neutral metals in the stellar atmospheres — particularly calcium, sodium, and magnesium — that nearly eliminates the blue and violet portions of the spectrum. The spectra of carbon stars are so complex that astronomers have considerable difficulty evaluating the stars' temperature, but it is known that they extend downward toward 2000 kelvins.

The distinction between the giant carbon stars and ordinary M giants is found in their different carbon-to-oxygen ratios. Carbon and oxygen have a great affinity for one another, but if there is less carbon than oxygen in a star's atmosphere, the leftover oxygen forms metallic oxides that dominate the spectra with their absorbing power. If, on the other hand, there is more carbon, all the oxygen gets used up in carbon compounds, and the excess carbon combines with itself. On the cosmic scale oxygen is the more abundant. In the Sun the carbon/oxygen ratio is 0.6, but in the carbon stars it is between 1 and 1.2.

We are actually seeing stars alter their compositions as they age. The transformation begins on the asymptotic giant branch and seems to affect only low-mass stars. The helium that burns in the shell around the core leaves behind a carbon residue. Energy can be transported to the star's surface by convection: hot



**THE DUSTY SHELL** around the carbon star IRC +10216, revealed in this false-color image, contains over twenty different kinds of molecules. The deduced sizes of the central star (0.04") and the inner boundary of the shell (0.2") are shown by the circles. Photo courtesy of J.C. Christou and S.T. Ridgway of the National Optical Astronomy Observatories, C.A. Haniff of Caltech, and D. Buscher of the Mullard Radio Astronomy Observatory, Cambridge, England.

gases rise from below, release their energy, cool, then sink. Under particular circumstances that astronomers are only now beginning to understand, the convection currents can dip into the carbon-rich zones and bring the element to the surface.

Since the process is gradual and depends on mass, astronomers expect to see intermediate cases. And they do. In between the M-class stars and the carbon stars is another class called S, for which the carbon/oxygen ratio is about 1. The S stars were originally recognized by zirconium oxide bands in their spectra, which replaces titanium oxide. Zirconium has a greater affinity for oxygen than titanium does, so that when carbon is equal to oxygen the small amount of oxygen is preferentialy used up by the zirconium, leaving none for the titanium.

Carbon is not the only element manufactured and dredged to the stellar surface via convection. The nuclear reactions in the burning shells release large numbers of free neutrons that can attach themselves to lighter elements to build heavier ones through the "s-process" (s for slow, because it proceeds slowly). Zirconium is one of the s-process elements and it also becomes enriched, adding to the S-star effect. Astronomers, in fact, see a whole range of types from class M to C, including intermediate MS and SC stars.

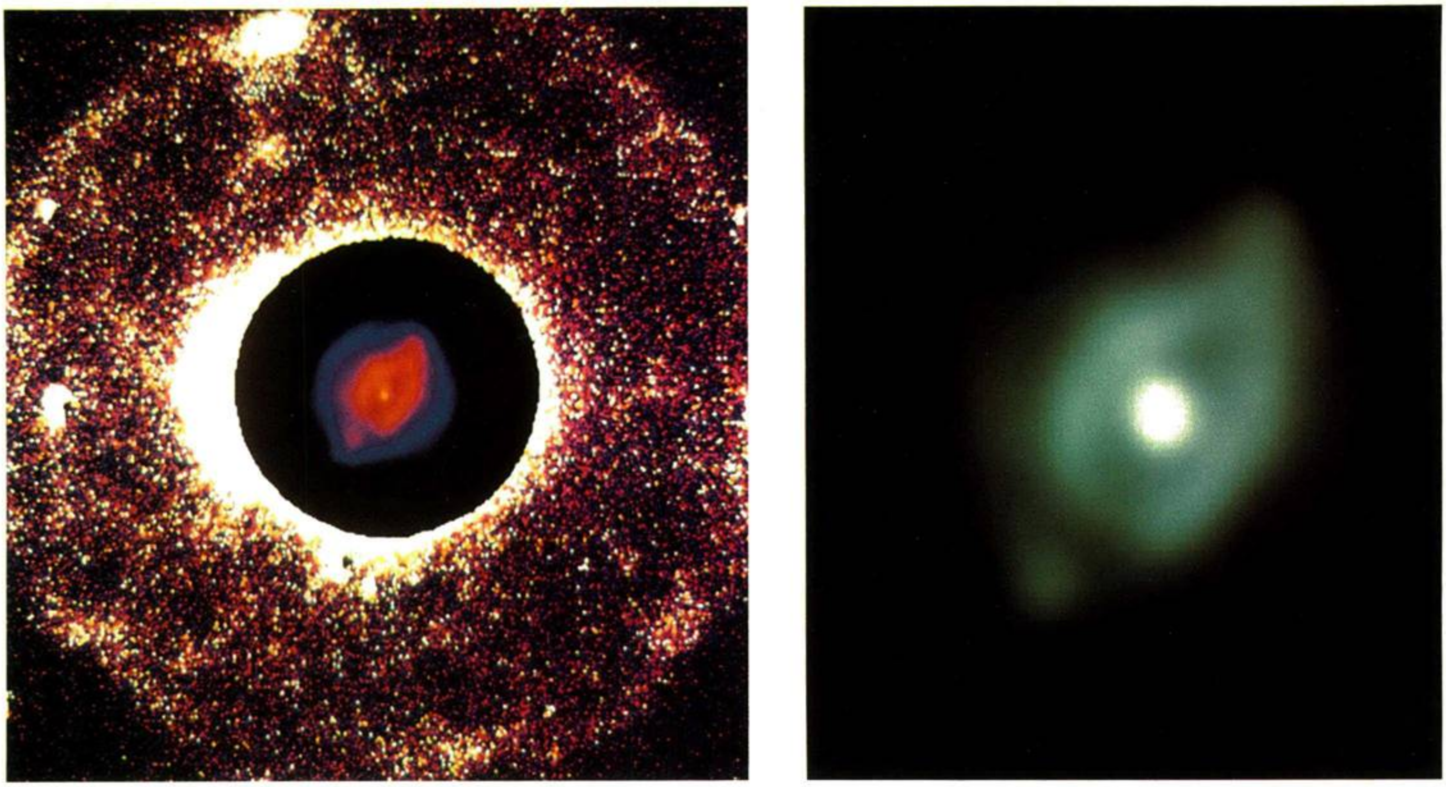
Proof that we are witnessing the actual creation of elements comes from observations of the element technetium. This substance, number 43 in the periodic table, is highly radioactive and long ago disappeared from the Earth's crust. It has a half-life (the time it takes for a radioactive element to decay to half its original amount) of only 200,000 years, far less than the lifetime of a star. If it were not freshly manufactured by the s-process and brought to the surface it could not possibly be seen: truly modern-day alchemy.

## Giant Variable Stars

A fundamental fact of life for these cool M, N, and S stars is that their brightness intrinsically varies. Variable stars are remarkably common. They are found everywhere on the H-R diagram, but concentrate heavily along the "instability strip" running down the center of the diagram through classes G, F, and A, and in the realm of the M giants.

The variations are caused by internal effects that make the stars of the central instability strip expand and contract with remarkable regularity. The pulsation results from the ionization of hydrogen or helium in layers that are at just the right depth and which render the star unstable. As the star pulsates, the internal temperature and density change. Ionization takes energy, and any change in temperature, which affects ionization, causes the ionizing layer to act as a valve that absorbs or releases radiation. The valve and the pulsation feed back into one another and the pulsation continues until evolution causes the internal structure of the star to change.

One of the most notable classes of pulsating variables is the class F supergiant Cepheid stars (named for the prototype, Delta Cephei). Typically, Cepheids vary by a magnitude or two, with periods ranging from roughly 2 to 100 days. But the cool M or carbon variables, which operate on the same basic principles, are so large that they take much longer — a year or more



**A GIANT STAR'S FINAL ACT** is to blow off mass and form a planetary nebula. At left is the inner portion of NGC 6826 showing the bright central star, an inner rim of newly ejected material, and two outer knots. The photo at right shows the nebula's outermost halo. The bright blobs are probably areas where the expanding gas is colliding with denser regions in the interstellar medium. Photo courtesy Philip Plait and Noam Soker, University of Virginia.

— to change in brightness. Consequently, they are termed long-period variables. The most famous example is the star Mira. This amazing body varies from 2nd or 3rd magnitude to 10th and back over a period of about 330 days. Consequently, long-period variables are more commonly called "Miras." The Mira variables can be of spectral class M, S, or N. The best example of an S-type Mira is Chi ($\chi$) Cygni (3rd to 14th magnitude in 406 days). The most famous N Mira is probably R Leporis.

The huge visual variability is deceptive. Mira stars are all so cool that most of their radiation emerges in the infrared where the eye cannot see. To infrared-sensitive detectors the star varies by only a magnitude or two. When it dims and cools, additional titanium oxide molecules form in the star's atmosphere, which reduces the optical brightness even more. The star's radius and temperature also influence the light variations differently at different wavelengths. Since temperature both changes with radius and increases with depth, and we see to different levels in the star's atmosphere at different wavelengths, the optical and infrared peaks don't occur at the same time. The optical peak precedes the infrared peak by up to two months.

### Mass Loss and Masers

Perhaps even more remarkable than their variability is the astonishing amount of mass lost by the red giants, particularly by the Mira stars in the asymptotic giant phase. They become so distended that the surface gravities become very small, allowing matter to escape. The effect is greatly enhanced by the energy generated by pulsation. As evolution proceeds and the stars grow larger, the periods of variability increase along with the rates of mass loss. By the time the star has reached the top of the asymptotic giant branch it is losing matter at the rate of 0.0001 solar mass per year. While this number may seem small, keep in mind that the star can be in this state for thousands of years. Ultimately, it may blow off half or more of itself (depending on initial mass) back into space as it begins to expose its core.

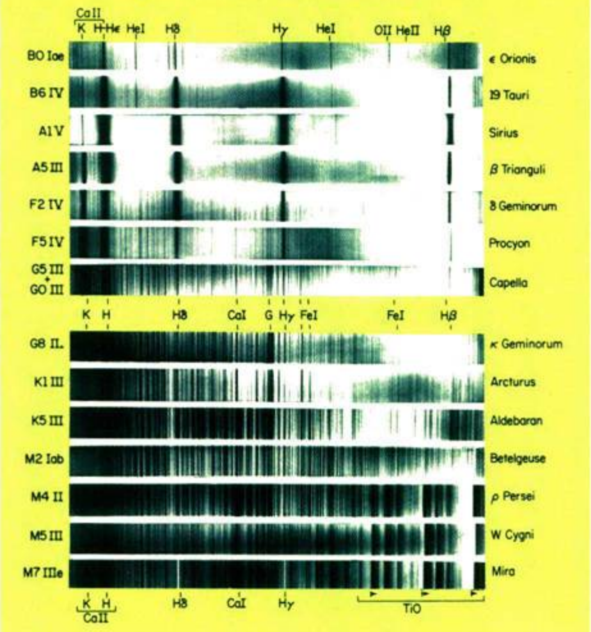
As matter flows outward, the Mira gradually encloses itself in a cocoon of its own making. Dust particles form out of the now-cold gas and hide the star from view in the optical part of the spectrum. But since the starlight heats the dust grains to a few hundred degrees, the shroud glows brightly in the infrared, revealing the celestial location of the now-mysterious star. The *Infrared Astronomical Satellite* found large numbers of these objects in 1982.

The nature of the buried stars is readily revealed by the spectral signatures of the outflowing dusty envelopes. Emissions from silicate grains made of oxygen and silicon, characteristic of an M-type oxygen-rich Mira, can be seen in the infrared. Radiation from silicon carbide can also be evident, which shows that a carbon star is buried within.

The dust is critically important in the mass-loss process itself. According to modern theory the pulsations, perhaps by means of the shock waves, lift the gas outward to the point where it is cool enough for grains to form. Radiation pressure from the star pushes the dust away, which then drags the gas along with it.

The cold conditions of the expanding envelope

## The Spectral Classes



**COOL STARS DISPLAY** a thicket of molecular absorption lines and bands, while hotter stars exhibit hydrogen absorption and ionized calcium (CaII). The G feature is the molecule methyladine. Courtesy of the University of Michigan.

also favor the production of molecules such as silicon monoxide (SiO) and hydroxyl (OH), which are detected in the radio spectrum. Together these molecules and the stars' infrared radiation give evolved Miras the generic name "OH/IR stars." The OH radiates as a natural maser. The maser is the microwave version of the familiar laser, an acronym for the light amplification by the stimulated emission of radiation.

Essentially masers are created by stimulating excited molecules to emit photons in phase with the passing radiation. Recall that a ray of light with just the right energy can raise an electron from a lower orbit to an upper one. But light can also stimulate an electron that is already in an upper orbit to drop downward, increasing, or amplifying, the intensity of the light ray. In a normal gas there are always more electrons in lower orbits (lower energy states), so there is never any net amplification of incoming light — absorptions and emissions just balance one another. However, if the orbit populations are inverted, that is, if more electrons are in upper orbits than in lower ones, the stimulated emissions dominate and the beam can become powerfully amplified. Both the stimulated and the original stimulating photons move off in the same direction, the result being a narrow, highly directed beam of radio radiation.

The problem is to "pump" the gas with the right amount of energy to raise the electrons to their upper orbits in the first place. In a Mira star the pumping is done by the star's own infrared radiation: The radio lines actually vary with the same period as the star.

The intense OH maser lies in a thin shell some 10,000 astronomical units across. As seen from Earth the backside of the shell is receding, so its radiation is Doppler-shifted to longer wavelengths. The front side, however, is moving toward us, so its radiation is shifted to shorter wavelengths. The result is that the OH line shows two components that are displaced relative to one another. From this astronomers deduce expansion velocities of 10 or 20 kilometers per second — a rather gentle stellar wind.

Since the maser is pumped by the star, the maser variations must follow the stellar variations, but delayed by the time it takes the star's light to get to the molecular zone where the maser is generated. What is actually observed is that the stellar and maser line peaks are out of step with one another by the light travel time across the shell. To find the shell's diameter, all astronomers have to do is measure the time between the maximums of one peak and then the other and divide by the speed of light. With a velocity of 10 kilometers per second, the wind must have been blowing for nearly 3,000 years to reach a radius of 5,000 AUs, which gives a rough idea of how long the star has been in this state. And with a mass-loss rate of 0.0001 solar masses per year, some several tenths of a solar mass must be tied up within the dusty confines of the shell.

The OH shells are so large that their angular diameters can be measured (several arcseconds, even when 3,000 light-years away). This value, when combined with the physical diameter, yields distance. Clearly these stars are a treasury of information!

The dusty shells around the carbon Miras are even stranger. Here there is little maser emission, but carbon has the propensity to form complex molecules. In the prototype object, called only IRC +10216, we see over twenty different kinds, including such complex organic constructions as cyanotriacetylene ($HC_7N$) and methyl cyanide ($CH_3CN$). Both the carbon and the OH/IR Miras are of great significance in the evolution of the Galaxy. The outbound matter populates the interstellar medium — the stellar nursery — with different kinds of dust and slowly but steadily enriches it with heavier elements. We can think of stars as vast recycling engines that pump the bulk of their mass back into space to create new generations of stars and, perhaps, planets and life.

The coolest stars include a wonderful fund of fascinating objects. They have vast brightness and size ranges, by far the most complex spectra, and a puzzling evolutionary infrastructure. Moreover, because the giant phase is such an ephemeral period in the life of a star, astronomers can only guess at some of the evolutionary details. All this makes comprehending the nature of the coolest stars a monumental task, but one with great potential for enriching our knowledge of stars in general. □

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*James B. Kaler is a professor of astronomy at the University of Illinois, Urbana-Champaign. His previous article, "Realm of the Hottest Stars," appeared in the February 1990 issue. A version of this article appeared in the Italian astronomy magazine l'Astronomia. Kaler's articles on stellar superlatives will be published in book form by Cambridge University Press.*

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# A New Look at the Crab Nebula

Radio observations and powerful supercomputers have combined to give astronomers a fresh view of this supernova remnant.

by Gerrit L. Verschuur

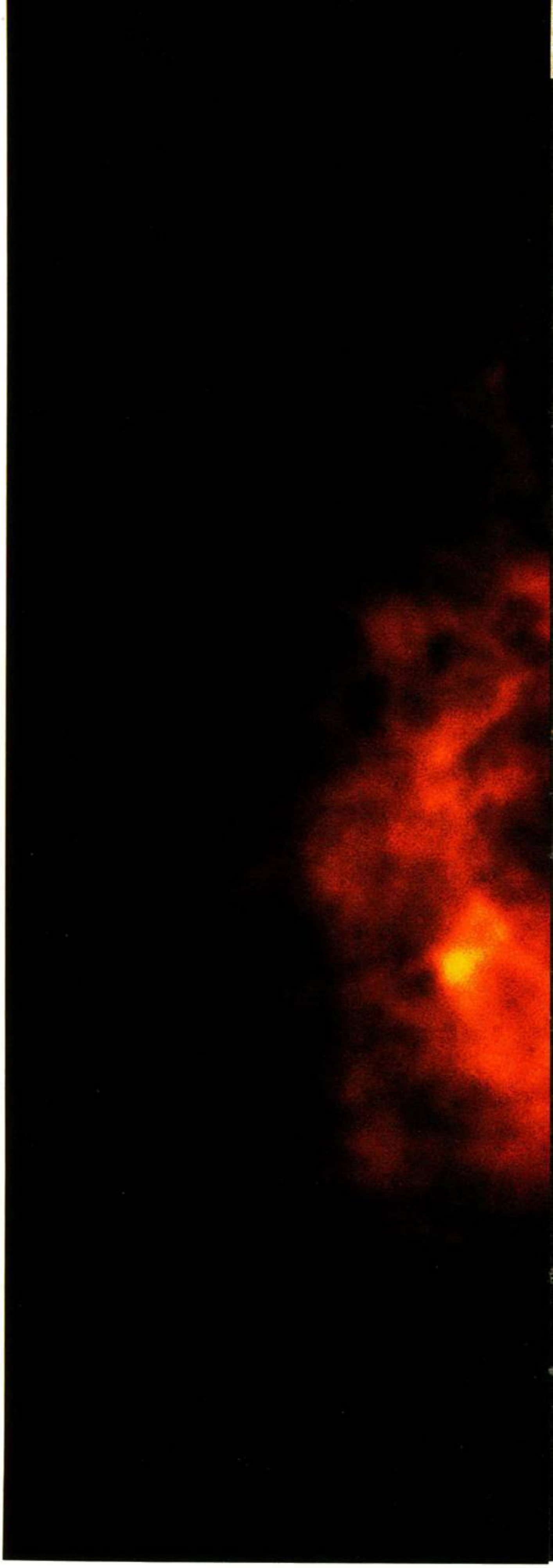
The Crab Nebula in Taurus has always held a special fascination for astronomers. Born of a supernova, the nebula's unique shape and easy visibility have fascinated sky observers for several centuries. The Crab's slowly expanding shell of gas and peculiar synchrotron emission have been studied by astrophysicists for decades. Now, after seven years of study, astronomers have given us a new look at an old crustacean.

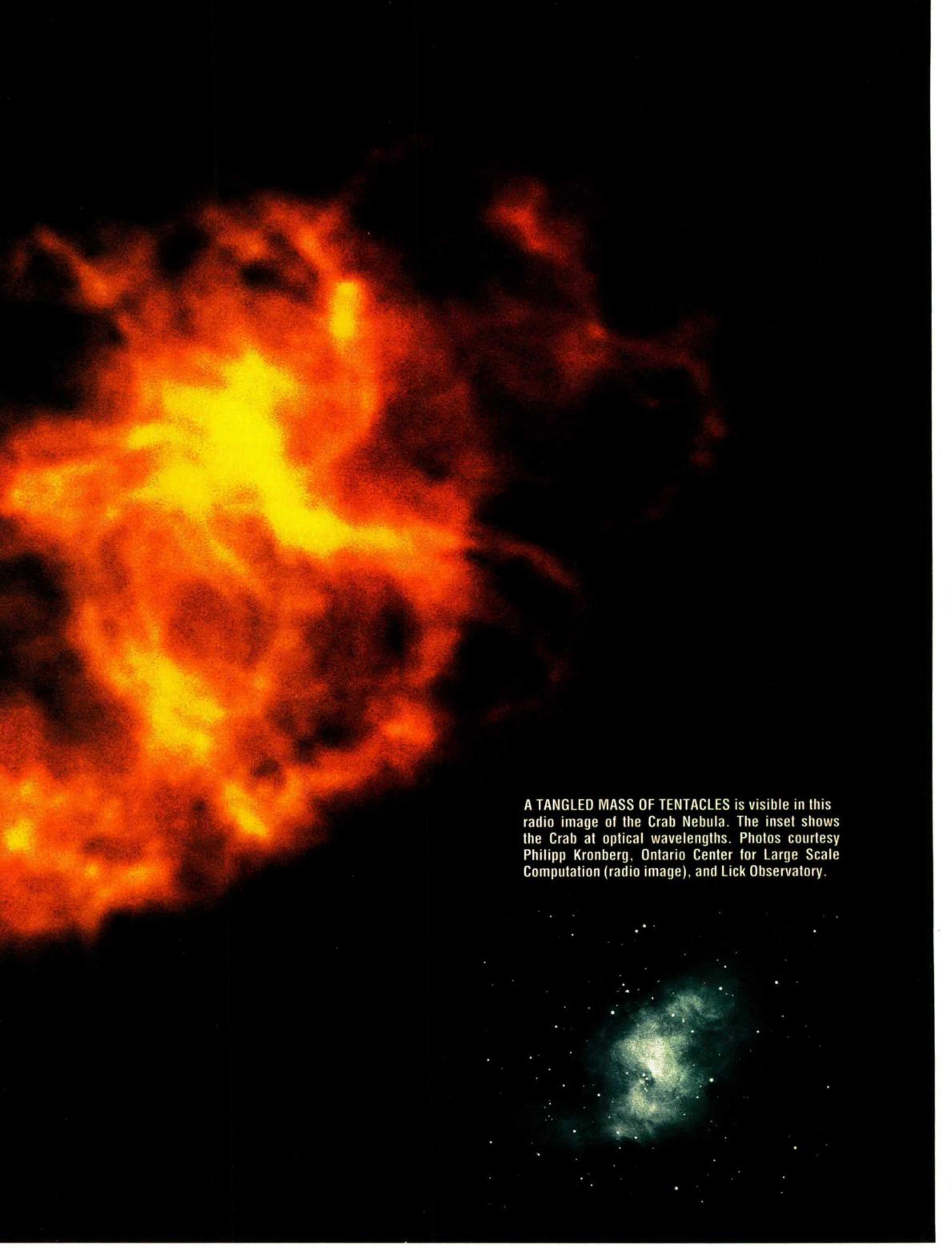
Two radio astronomers at the University of Toronto have produced a detailed radio image of the Crab as part of their research into how the Crab's tentacles are moving. Michael Bietenholz and Philipp Kronberg used radio observations from the Very Large Array radio telescope in New Mexico to produce a detailed radio image. "Comparing our image with another made in 1982 gives us the most detailed look at the physical properties of a supernova remnant ever made," said Kronberg. So many bits of data were required to produce the image (59.4 megabytes to be exact) that a CRAY X-MP/24 supercomputer at the Ontario Center for Large Scale Computation had to be used to generate the images. "We used fifteen hours of number-crunching time on the Cray, much less than the 180 days an ordinary computer would require," said Kronberg.

The Crab Nebula is recognized as unique among supernova remnants. It does not have the expected shell-like structure of a remnant. If any shell exists it is filled with twisting filaments and glowing matter.

The Crab has a fascinating history. On July 4, 1054, Chinese astronomers unknowingly witnessed the moment of birth of this object when a "guest star" appeared just southeast of Zeta Tauri. It reached a peak magnitude of –3.5 and was so bright that it was visible during daylight for nearly a month. It faded from the night sky a year and a half later.

In 1731 John Bevis, an English physician, found a fuzzy nebula at the location of the guest star. No one paid much attention to Bevis' discovery until Charles Messier rediscovered it while trying to find Halley's Comet in 1758. He saw a "whitish light, elongated in the form of the light from a candle, not containing any star" in the constellation Taurus. An inveterate comet hunter, Messier found himself distracted by these fuzzy nebulae. For the benefit of other comet hunters he made a list of these nebulae to prevent confusion with comets. The first entry, known afterward as M1, was





A TANGLED MASS OF TENTACLES is visible in this radio image of the Crab Nebula. The inset shows the Crab at optical wavelengths. Photos courtesy Philipp Kronberg, Ontario Center for Large Scale Computation (radio image), and Lick Observatory.

the object Bevis had originally spotted.

Around 1845, William Parsons, the Third Earl of Rosse, made a sketch of M1 while observing the object with his 72-inch "Leviathon" telescope. His sketch bore a vague resemblance to a giant bug. He christened the object the Crab Nebula.

Astronomers in the early 1900s noticed that the nebula resembled neither Lord Rosse's sketch or a crab. In 1921 Carl O. Lampland of Lowell Observatory compared photographs taken eleven years apart and found that the nebula was expanding at a rate of about 2.25 million miles per hour (1,100 kilometers per second). No wonder the Crab had changed its appearance since Lord Rosse's time.

In the 1950s the Crab Nebula provided the key that led to the solution of the mystery of how cosmic radio sources emit radio waves. Immediately after World War II physicists built the world's first synchrotron at the General Electric Company in Schenectady, New York. Its strong magnetic fields urged electrons into ever more frenzied gyrations around the innards of the device before they were driven headlong into the nucleus of an atom.

When the synchrotron was fired up for the first time physicists watching through a window saw the particle beam begin to glow. At this point in a science fiction movie the heroes would have run headlong for the exits. But the physicists stayed and watched in fascination as the light changed color from dull red at low energies to blue-white when the synchrotron was at full throttle.

**Comparing our image of the Crab with one made in 1982 gives us the most detailed look at the physical properties of a supernova remnant ever made.**

Using a Polaroid filter, they found that the light was polarized. This came to be known as synchrotron emission, which is created when electrons traveling near the speed of light (cosmic-ray electrons) encounter magnetic fields. The fields cause the electrons to spiral as they travel. In the process they loose energy, which is radiated away as polarized light. The precise nature and intensity of the emission and the wavelengths over which it can be observed depend on the energy of the electrons and the strength of the magnetic field.

In 1953 the Russian astrophysicist Iosef S. Shklovski suggested that this process was responsible for the light and the radio waves from the Crab Nebula. When the following year the nebula's light was found to be polarized, few doubted that Shklovski was correct.

There remained one annoying fly in the ointment, however. The nebula was emitting so much energy that the cosmic-ray electrons created in the explosion should have stopped creating photons after 200 years. Yet there was the Crab Nebula still shining 900 years after the guest star exploded. How was that possible? In the 1970s the answer was found. A pulsar at the heart of the nebula acts as the engine that provides energy to drive the synchrotron light show. (See "On the Trail of Exotic Pulsars" by Gerrit L. Verschuur, December 1988.)

Images of the Crab Nebula made at radio and visible wavelengths reveal different internal structures and processes at work. The glow of light seen behind and between the filaments in visible light is due to synchrotron radiation. The light from these filaments, however, is generated by a totally different process. The electrons are moving slowly, far below the speed of light, at about 20 kilometers per second. These particles are part of the gas from the original explosion that is kept hot by ultraviolet light generated by the synchrotron process in the more violent parts of the nebula. Thus the visible filaments radiate thermal emission that is more characteristic of the surface of the Sun and objects such as the Orion Nebula.

In a radio image a different set of filaments is revealed. These are magnetic structures that intermingle with the visible ones. The nebula also appears somewhat larger than the optical nebula. Apparently, radio-emitting clouds have expanded faster and reached farther into space than the hot gases.

Bietenholz and Kronberg are especially intrigued by the relationship between the interacting sets of filaments. By observing the detailed structure, motion, and polarization in the Crab, the researchers hope to uncover the dynamical soul of this nebula.

The turbulent filaments of the Crab Nebula fascinate Bietenholz and Kronberg. By comparing two radio images taken five years apart, they can probe the energetics of the Crab supernova explosion. Kronberg admits that the motions they have seen so far, based on the first look at the data, are extremely complex.

The Crab Nebula is 6,500 light-years distant and has an angular diameter of 6' by 4'. This translates to about 10 light-years across. The nebula enshrouds from three to six stars. Stars that end their lives as supernovae have to be relatively massive and quite young, something like tens to hundreds of millions of years old. This was not enough time for the emergence of even the simplest life on any planets that might have orbited the star that exploded to produce the Crab Nebula. However, the same is not true of planets around older stars that just happened to find themselves in the vicinity of the explosion. If life ever took hold on any planets orbiting these stars, it has long since ceased to exist. X-rays and ultraviolet light from the explosion, as well as the cosmic-ray electrons in the remnant, are lethal and would have caused total extinction.

This tale of life and death is played out again and again somewhere in the Galaxy every time a supernova erupts. Fortunately for us, there are no suitable stars within hundreds of light-years of Earth that are likely to explode as a supernova any time soon. As regards the fate of life on other planets, it's just a matter of luck as to whether or not it runs into something like the Crab Nebula and life is set back to square one. But once the Crab has faded out of existence and blended with other matter between the stars, life may rise anew, heedless of the fate of countless species that had gone before. ☐

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*Gerrit L. Verschuur is a freelance science writer and radio astronomer living in Bowie, Maryland. His last article in ASTRONOMY was "The Peculiar Pulsar in Supernova 1987A," September 1989.*

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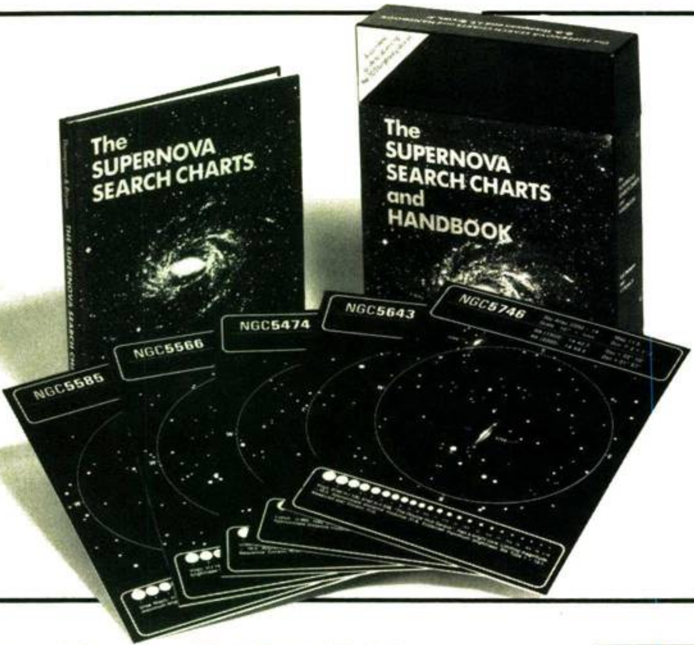
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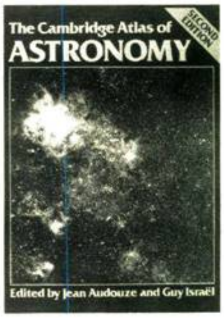

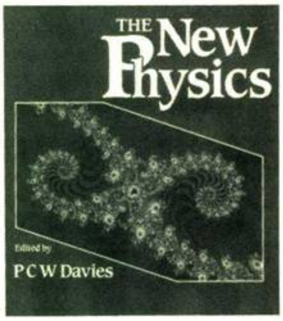

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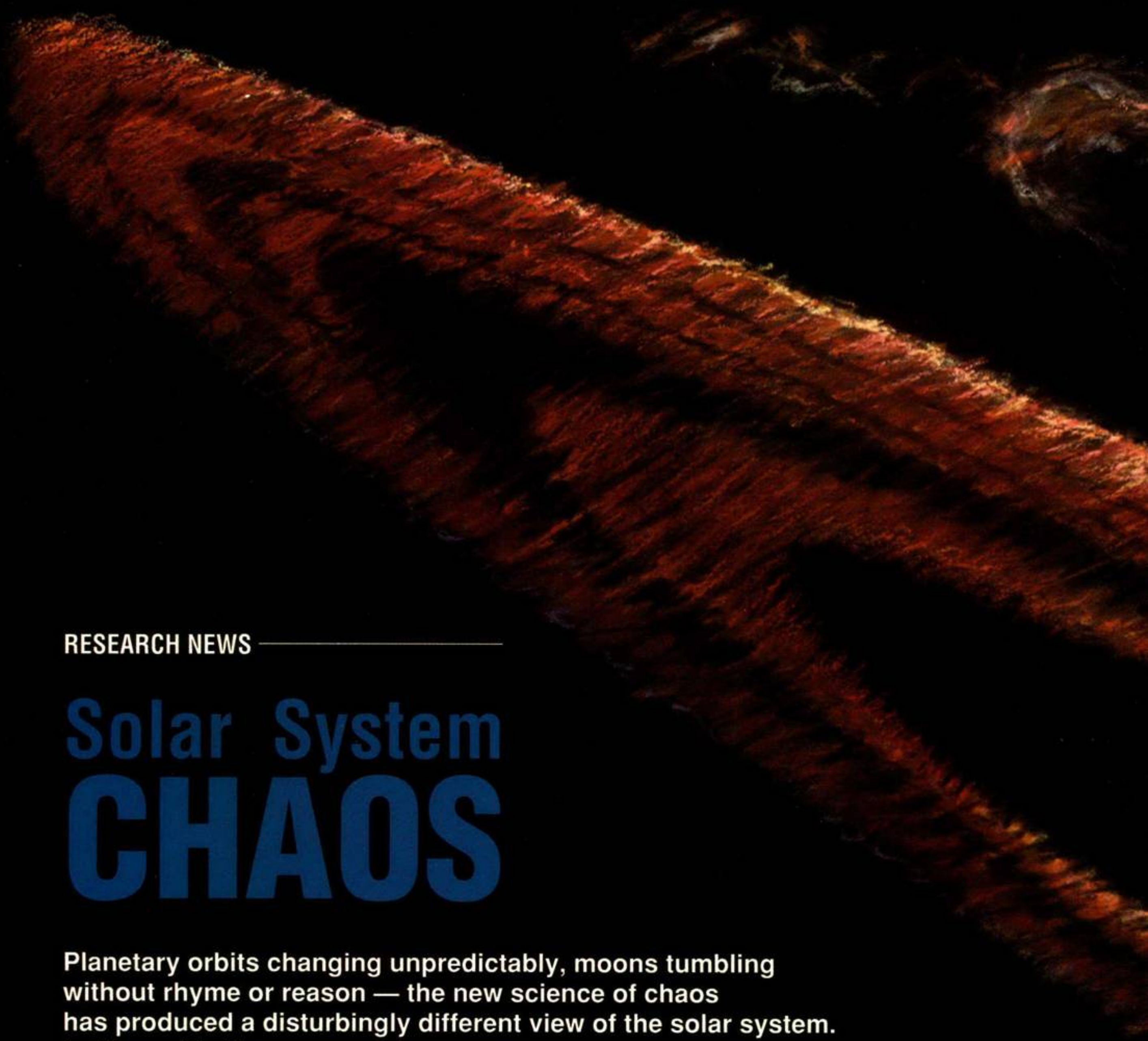


RESEARCH NEWS

# Solar System CHAOS

**Planetary orbits changing unpredictably, moons tumbling without rhyme or reason — the new science of chaos has produced a disturbingly different view of the solar system.**

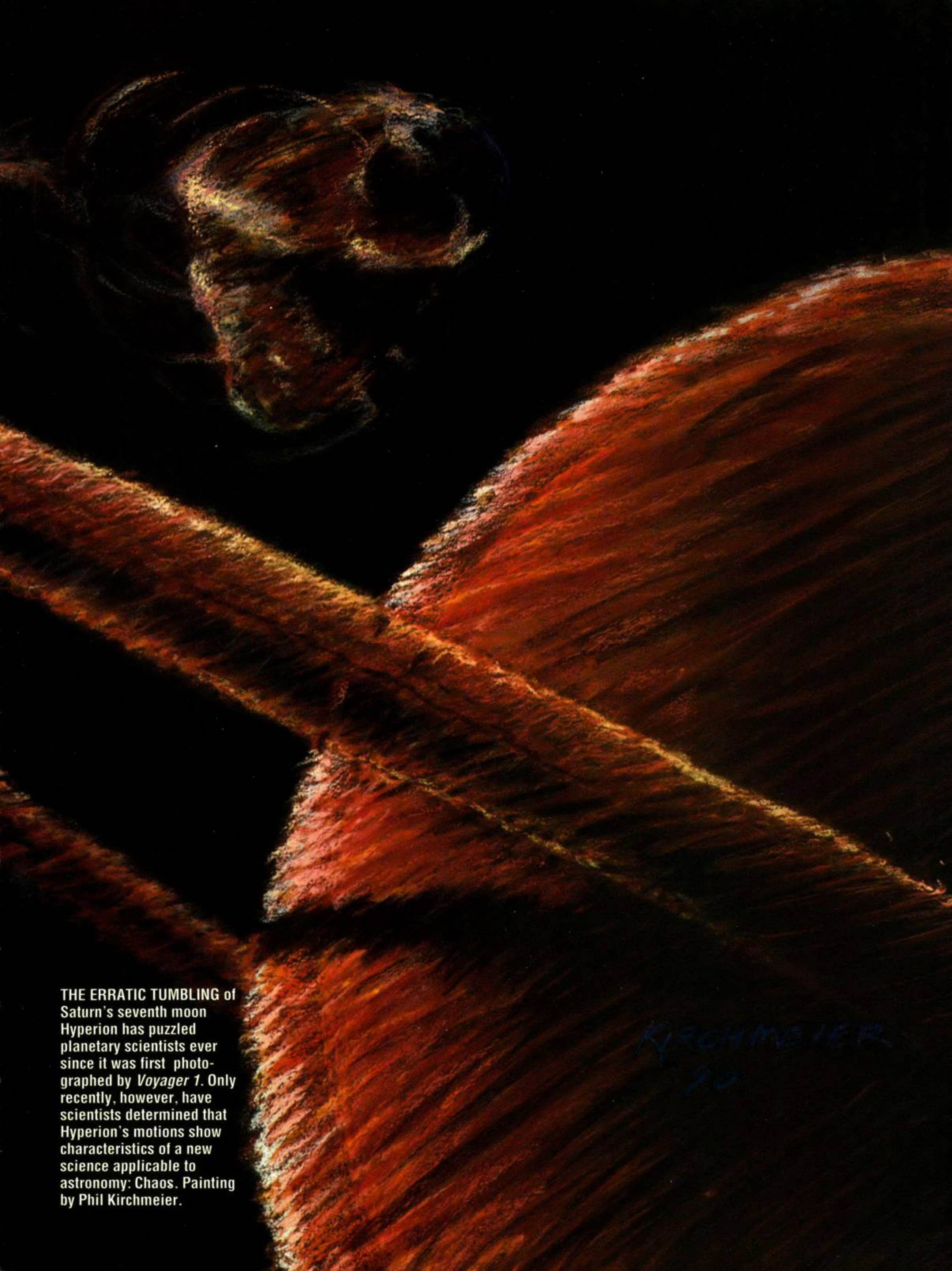
**by Karen Hartley**

While much on this Earth seems uncertain — paychecks arriving, cars starting in bad weather, the opposite sex behaving predictably — most people have rested assured that, at the very least, they could count on the solar system to stay stable. After all, it's been around for more than 4 billion years. If that isn't a good track record, what is?

Some recent findings, however, have thrown a monkey wrench into this kind of thinking. Astronomers have uncovered certain kinds of instabilities that occur throughout the solar system — in the motions of Saturn's moon Hyperion, in gaps in the asteroid belt between Mars and Jupiter, and in the orbits of the system's planets themselves. Researchers are now arguing that these instabilities are the result of "chaos," a relatively new science that seeks to understand and explain the motions of complex dynamical systems.

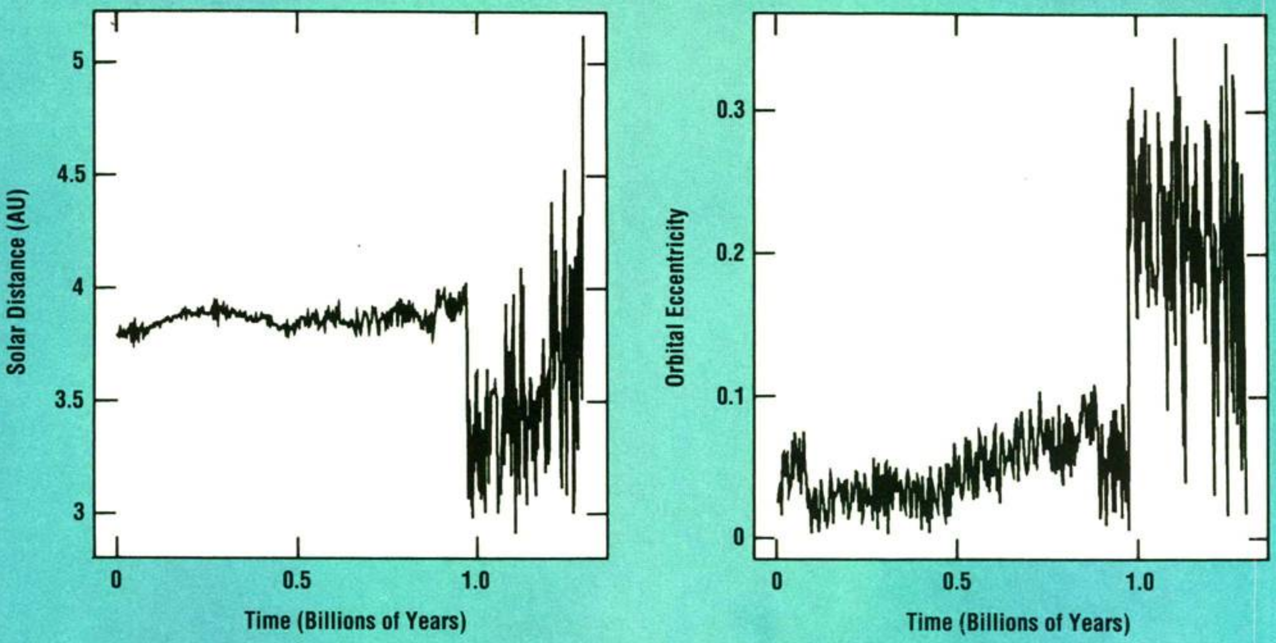
As used by astronomers, the word chaos denotes an abrupt change in some property of an object's orbit, such as its orbital inclination or eccentricity. An object behaving in a chaotic manner may, for example, have an orbital eccentricity that varies cyclically within certain limits for thousands or even millions of years, and then abruptly its pattern of variation changes. The result is a sharp break in the object's history — its past behavior no longer says anything about its long-term future behavior.

The science of chaos isn't wholly new, despite its new-found applications in astronomy. Moreover, astronomers have long known that the solar system does not run with the precision of a Swiss watch. For centuries they have sought to predict planet positions from Newton's laws of motion, treating the Sun's fam-



**THE ERRATIC TUMBLING** of Saturn's seventh moon Hyperion has puzzled planetary scientists ever since it was first photographed by *Voyager 1*. Only recently, however, have scientists determined that Hyperion's motions show characteristics of a new science applicable to astronomy: Chaos. Painting by Phil Kirchmeier.

## Chaos in the Asteroid Belt



Chaotic behavior can begin abruptly. These two diagrams from the work of Martin Duncan, Thomas Quinn, and Scott Tremaine show the changes in solar distance (left) and orbital eccentricity (right) for a test object that began in a circular orbit at 3.8 astronomical units. Note the dramatic change starting at the billion-year mark.

ily like a kind of gigantic clock. But the real planets in the sky have never behaved quite as neatly as the planets in the equations.

This problem stems from two difficulties, the first theoretical, the other practical. The theoretical difficulty was summed up by the work of French mathematician Henri Poincare around the turn of this century. He demonstrated that while astronomers can easily predict how any two bodies — Earth and the Moon, for example — will travel around their common center of gravity, introducing a third gravitating body (such as another planet or the Sun) prevents a definitive analytical solution to the equations of motion. This makes the long-term evolution of the system impossible, in principle, to predict.

To get around this impasse astronomers have carefully observed the movements and gravitational interactions of the planets and have developed sophisticated equations to describe them. To an extent, these equations are successful: They can calculate the perturbations due to gravitational interactions with an accuracy that is extremely high, even if it falls short of a totally rigorous prediction. Thus, although the three-body problem is formally unsolvable (as Poincare proved), one can get *approximate* solutions to it with almost any degree of accuracy required. The only snag comes with the second difficulty, the practical limits of computer power.

In Poincare's day orbital perturbation calculations were done by hand using cumbersome, eye-straining tables of logarithms. An enormous boost came when the first electromechanical tabulating machines and desk calculators appeared in the early years of this century. But even with their assistance, detailed, long-term orbital projections were too lengthy to be undertaken.

Therefore, the business of predicting planetary motions over the long term lay dormant until the mid-1950s when two things happened. First, electronic computers were used to ease the burden of calculation. Second, a theorem was developed to explain the evolution of dynamical systems like the solar system. The theorem said that a system undergoing slight perturbations will remain, for the most part, stable. This result was later extended to show that the solar system will remain stable when planet masses, orbital eccentricities, and inclinations all remain small.

But unfortunately the theorem proved unworkable when astronomers tried to use it to predict the system's actual stability. For years astronomers struggled with the issue. They attacked the problem mainly by means of perturbation theories in which one *ad hoc* term after another was tacked on to account for the interactions of planets and their resulting motions. But these perturbation theories failed, primarily because they were too approximate. Applied to long time scales they contained errors that accumulated until the results became worthless.

The advent of large and fast electronic computers in the 1960s brought a capability for more accurate research. In 1965 two astronomers teamed up to forecast the stability of the outer five planets for 120,000 years and later extended this calculation to a million years. In that work they found that Pluto's orbit displayed resonances, or periodically repeating gravitational interactions, with Neptune. On its surface, this finding looked innocent, yet viewed in retrospect it was actually the first sign of solar system chaos. In 1985 another group forecast the motions of the outer five planets 5 million years into the future. They verified the earlier results about Pluto's orbit, but once again didn't find anything that appeared very unusual. Thus, as recently as five years ago it seemed like the solar system would remain stable for the lifetime of the Sun.

From today's viewpoint it is clear that these researchers were just not looking far enough into the future. Handicapped by the time needed to forecast millions of years ahead, the researchers were stopping their computer runs before things really started to happen. When the advent of supercomputers finally gave researchers the power to tackle very long-term integrations of the motions of planets, intriguing results began to show up, and chaos was out of the bag.

New to astronomy, chaos is also an infant among the more well-established sciences. The first real strides in chaos theory came in 1963 at the Massachusetts Institute of Technology when meteorologist Edward Lorenz studied a real-world system — the weather. Lorenz wanted to explain the unpredictability of the weather and went about modeling global weather patterns with a computer.

What he found surprised him. Changing the initial inputs only slightly caused drastic changes in how the model system evolved. This ran directly counter to the experience of most scientists, who with good reason believe that slight changes in a system's initial conditions will generally cause only slight discrepancies in the results. Lorenz' findings upset that belief because they showed that even a subtle change could on occasion radically alter the way a system behaved. This sensitive dependence on initial conditions is a hallmark of chaotic systems.

Another way of describing this aspect of chaos is that it involves systems that don't frequently make for straightforward solutions. Called nonlinear, such systems often "blow up." For example, changing the input by 1 percent in a model may create a new outcome that differs several fold from the original outcome. Thus as one varies the initial properties only slightly, the changing outcomes diverge from each other with exponential rapidity.

Lorenz also discovered something else. When he plotted the results of an experiment that modeled atmospheric convection, a strange pattern emerged. The results produced a distinct repetitive pattern (nicknamed Lorenz' Butterfly, from its shape on a graph) that exhibited an odd kind of order. He found that eventually every system settles down, or is "attracted," to some kind of order, much as a glass of water settles down to a steady state after being shaken. The point to which Lorenz' Butterfly settled down became known as a "strange attractor." This is the term given by chaos theory to any state that a system can settle down to, at least temporarily, and which places some limits on what the system can do.

One of the first cases of chaos to be recognized in the solar system came when Jack Wisdom, then of the University of California at Santa Barbara, became intrigued by the motions of Saturn's moon Hyperion. And for good reason. *Voyager 2*'s flyby of the moon in 1981 revealed some interesting facts: Hyperion is an irregularly shaped blob that appears to be wobbling and spinning at erratic rates as it moves in its elongated orbit. (*Voyager 1* did not get a good look at Hyperion when it flew past nine months before *Voyager 2.)* Wisdom estimated that Hyperion's spin rate may have gone from no rotation at all to one rotation every 10 days in as few as two trips around Saturn. In addition, the moon's spin axis varied both in its space orientation and in its physical location on the moon.

Before the *Voyager* flybys astronomers had guessed that Hyperion, like Earth's Moon, would have been "de-spun" by tidal forces from Saturn. This means that the moon's spin rate would have slowed to the point where Hyperion would rotate on its axis in the same time it took to circle Saturn, and therefore would always keep the same side facing the planet, just as our Moon does.

So why hadn't Hyperion settled down? To explain the apparent anomaly, Wisdom and colleague Stanton J. Peale from UC Santa Barbara and Francois Mignard of the Research Center for the Study of Geodynamics and Astronomy in France theorized that Hyperion might have entered a chaotic zone in the relatively recent past. This zone is an orbit where the forces acting upon the moon balance so delicately that its future motions cannot be predicted with any certainty. The team theorized that Hyperion's rotation might have been disturbed when it entered this zone, which, coupled with the moon's irregular shape and elongated orbit, was enough to send it tumbling chaotically.

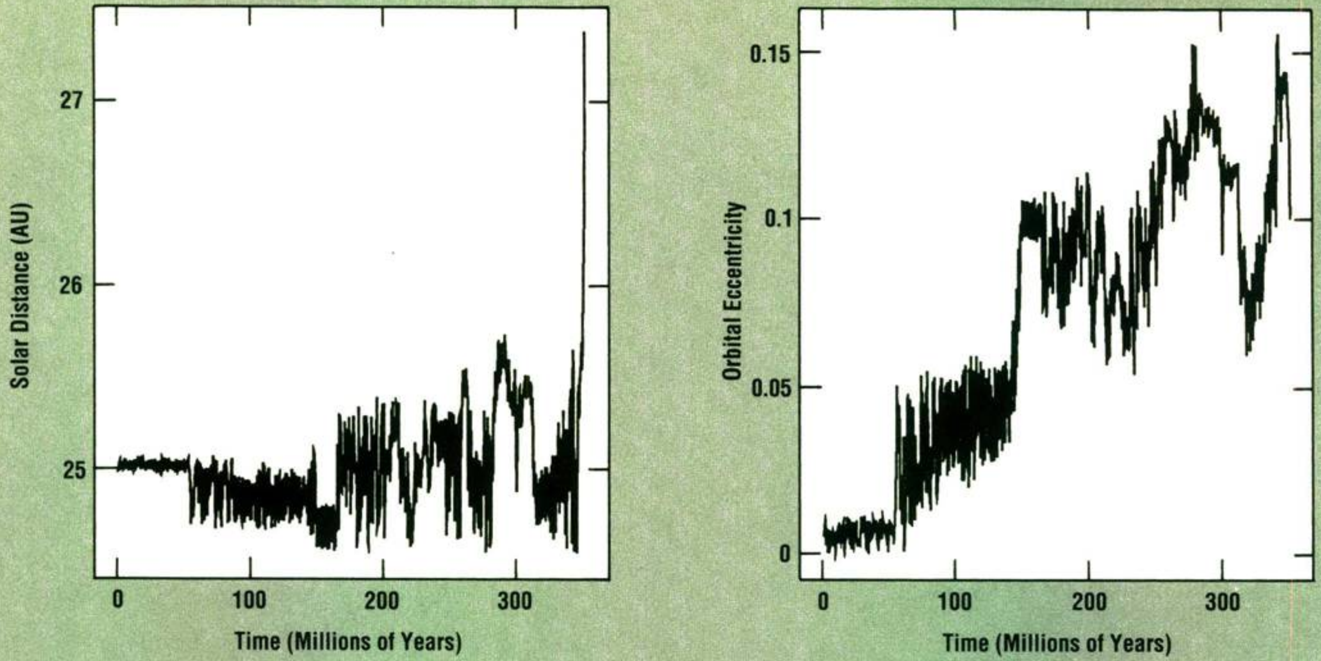
Unfortunately, with observational evidence from only two brief flybys the results have not been conclusive. Shortly after the team proposed its theory in early 1984, two other groups of astronomers found that Hyperion had a constant 13-day rotation period. While this is out of synch with the 21 days expected for synchronous rotation with Saturn, the 13-day period appeared to remain stable during the nine months that elapsed between the flybys. Almost two years later, however, a third group studying the Hyperion data suggested that the moon's light curve implied a rotation period of something other than 13 days.

Most recently, James Klavetter, Wisdom's graduate student at MIT, studied Hyperion's light curve with the McGraw-Hill telescope in Arizona. Klavetter's work showed that the light curve looks very much like it would if Hyperion were tumbling chaotically. "Hyperion is one of the neatest examples of chaos around," Wisdom said. "I don't think anyone today doubts that Hyperion is tumbling chaotically."

Wisdom has investigated other irregularly shaped natural satellites and concluded that all of them underwent some period of chaotic tumbling before they settled down to their present synchronous rotations with their primary planets. For example, Wisdom believes that even though Mars' moons Phobos and Deimos rotate regularly today, long ago they tumbled chaotically for periods of 10 to 20 million years and 100 million years, respectively.

In other research, Peter Goldreich and his colleagues at the California Institute of Technology proposed, just before the *Voyager 2* flyby of Neptune, a complicated hypothetical history for Neptune's moon Triton. They theorized that Triton was captured by Neptune out of an independent orbit around the Sun when it collided with one of the moons already circling Neptune. In their scenario, Triton's initial orbit was highly eccentric, but tidal forces made it nearly circular within a few hundred million years. In the pro-

## Chaos in the Outer Solar System



Just 50 million years is long enough for chaos to emerge in an object orbiting between Uranus and Neptune, according to the work of Duncan, Quinn, and Tremaine. Solar distance is graphed on the left and eccentricity on the right; the test object's initial orbit was circular at 25 AU.

cess Triton cannibalized most of the planet's regular satellites. Only those moons orbiting closer to Neptune than five planet-radii would have survived, and these would be perturbed into inclined orbits as a result of chaotic interactions with Triton.

Subsequent *Voyager 2* images revealed the existence of six new satellites on rather regular orbits close to Neptune. Although the existence of the satellites confirmed the team's theory that satellites close to the planet would have escaped being destroyed by Triton, the satellites' regular orbits were a surprise. Following the flyby the team reformulated its theory and proposed that Triton's chaotic perturbations could have caused these satellites to collide, fragment, and then reaccrete in their present regular orbits.

Besides having some of the solar system's satellites chaotically influenced, there is also evidence that slight chaotic instabilities exist elsewhere in the solar system. In the early 1980s Wisdom turned his attention to the mechanisms that govern the location of asteroids in the belt between Mars and Jupiter. The asteroid belt does not contain a population of bodies spread smoothly between Mars and Jupiter. Instead, asteroids tend to orbit only at certain fixed distances from the Sun, leaving other regions empty. It's like an LP record with some tracks left blank.

Many such empty orbits, called Kirkwood gaps after their discoverer, are known. They occur because an object orbiting in a gap has a period that is a regular fraction of Jupiter's. Such an object will undergo repeated gravitational perturbations from the giant planet and be slung out of that orbit on astronomically quick time scales.

Astronomers believe one particular empty gap in the belt might be the source for some of the meteorite impacts on Earth. However, they couldn't explain how the meteorites arrived at Earth at the high rate observed. The gap in question is where a particle in the belt revolves three times around the Sun for every circuit Jupiter completes. To explain the number of these meteorites that have been found, scientists had theorized that particles would be somehow shot out of the gap after spending only about a million years orbiting there. But no one knew just how the ejection process worked in detail.

What Wisdom found is that Jupiter's perturbations produce a chaotic zone at the gap. Particles that wander into the gap arrive with many different initial conditions. But because of the hair-trigger nature of a chaotic zone, these particles may end up with completely different dynamical states, including being flung out of the gap and being sent toward Mars or Earth. Wisdom found that one out of every five meteorites leaving that particular Kirkwood gap could be slung as far as Earth's orbit.

Wisdom's theory, originally conceived in 1983, was confirmed by George Wetherill of the Carnegie Institution of Washington. Wetherill found that Wisdom's predictions of how meteorites would be delivered to Earth by the chaotic zone matched the observed pattern of how certain types of meteorites, called ordinary chondrites, actually fell.

In 1986 Wisdom turned his attention to a new problem. He teamed up with Gerald Sussman of MIT's Artificial Intelligence Laboratory, who built a special computer optimized for integrating the equations of motions for small bodies moving in roughly circular orbits. The computer is called the Digital Orrery, after the old clockwork machines that modeled the motion of the planets in centuries past. This orrery, however, operates at about one-third of the speed of a Cray supercomputer! Wisdom and Sussman set the Orrery to work integrating the orbits of the five outer planets 107 million years into the past and 110 million years into the future.

Analyzing the results with other researchers from Columbia University, Caltech, and MIT, Wisdom noted an interesting fact about Pluto's orbit. The study found that the inclination of Pluto's orbit (about 17° at present) oscillated between 14.6° and 16.9° over a period of 34 million years. While they saw no real evidence of chaos, the researchers were suspicious of the results and decided to extend the integration to 845 million years, a computation that gave the Orrery five solid months of number crunching. Simulating the solar system in steps of 32.7 days, the researchers found that Pluto enters resonances with its neighbor Neptune that induce oscillations that last for periods of 3.8, 34, 150, and 600 million years at a time. And if Pluto's initial conditions are changed slightly, the orbital differences grow exponentially.

"In that calculation [845 million years] we found there was a level of divergence that was just below the level of detection in our first integration," Wisdom said. Making his own guess about Pluto's fate, Wisdom stated, "It has lasted for nearly a billion years without flying off. If I had to bet, I'd say it wasn't going to." But since its orbit is chaotic, he adds, really unstable motion can't be ruled out.

Italian researchers also recently calculated the motions of the outer planets for 100 million years in a study known as LONGSTOP, the Long-term Gravitational Stability Test for Outer Planets. Using a standard computer, Anna Nobili and Andrea Milani of the University of Pisa and Mario Carpino of the Astronomical Observatory of Milan concluded that the giant outer planets may show evidence of chaos. They found that instead of the small number of variations in orbital properties that ordinary resonances produce, the outer planets' orbits change over "periods" that vary in an open-ended way. Such behavior is characteristic of chaos.

In another study of the solar system's stability done last year, Jacques Laskar of the Bureau des Longitudes in France modeled the orbits of the inner planets over a long time scale. Using analytically simplified equations of motion, he looked at the planetary paths over 200 million years in 500-year steps and discovered three indications of chaos: the planets showed evidence of resonances, the system exhibited slight shifts in orbital patterns among the inner planets, and exponentially diverging differences emerged when he ran slightly varied test orbits.

"The predictability of the orbits of the inner planets, including Earth, is lost within a few tens of millions of years," Laskar concluded. He noted that this does not mean that we will see catastrophic events, such as Venus crossing the orbit of Earth. But he warns that the traditional tools of celestial mechanics, such as numerical integrations or analytical theories, cannot predict such events because the workings are, in the end, chaotic.

This also doesn't mean that the inner planets are likely to become unstable and randomly fly out of the solar system, says Wisdom. "It just means that you won't be able to predict the position of a planet in detail." For example, Earth will probably stay at roughly the same distance from the Sun, but you wouldn't be able to predict which side of the Sun it will be on.

While Wisdom and others were studying the stability of the planets, another group of astronomers was examining whether any existing bodies orbiting between the planets were stable. Martin Duncan of Queen's University in Kingston, Ontario, and Thomas Quinn and Scott Tremaine of the University of Toronto modeled three hundred test particles in a dynamical system that behaved like the solar system. They found that if the particles started out between Uranus and Neptune, the orbits of roughly half of them became chaotic enough over 5 billion years to be ejected from the solar system. (See pages 36 and 38.)

Were astronomers surprised when chaos began showing up in the solar system? "I think lots of people were surprised that there was chaos," Wisdom says. But he believes most astronomers accept that it exists. Tremaine agrees that many astronomers were surprised by the evidence of chaos: "The solar system has always been regarded as the classical example of the dynamical system that runs like clockwork."

How much of a role chaos has played in forming the solar system still remains an open question. Did the solar system settle down to its present configuration, where the planets are well spaced and following nearly circular, nearly coplanar orbits, in its first few million years? Or has it gradually evolved over the past 5 billion?

"No one knows," says Wisdom. "It seems to me conceivable that there may have been other planets" that may have been ejected, but he admits there is nothing to prove it. Although astronomers have tried to integrate the dynamics of resonances into the formation of the solar system, Wisdom thinks the problem is too full of physical uncertainties to be solved.

Says Goldreich: "It's possible that chaos played only a limited role in the dynamical history of the solar system," such as in the evolution of the asteroid belt and the clearing out of areas between the major planets. "But it's not at all clear that chaos has been important in clearing out the region between Venus and Earth or between Earth and Mars."

Goldreich also says that while Jupiter's chaotic zone and the tumbling of Hyperion "are clear cases" of chaos, whether chaos was necessary or important in producing gaps between all the planets "is a very open question." A question, he says, that with more powerful computers will likely be answered soon.

Whether the solar system will remain stable in the future is an open question, says Wisdom. Based on its stability so far, it is probably stable for geologically significant time periods, he believes. But as Tremaine says, chaos has shown that the solar system is by no means boring on long time scales.

And, as Wisdom said in a speech several years ago, "Apparently, even in a classical world, God does, after all, play dice." □

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*Karen Hartley is a freelance science writer living in Boston. Her most recent article, "Elliptical Galaxies Forged by Collision," appeared in the May 1989 issue.*

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**ASTROPHOTO OF THE MONTH**

**Comet Aarseth-Brewington 1989a1**, discovered by Howard Brewington ***using a 48mm LUMICON Swan Band Comet Filter!*** "The filter doubled contrast, making the comet very easy to spot," said Mr. Brewington. His 60 second photo on hypered 2415 (8" f/1.5) shows a nice tail.

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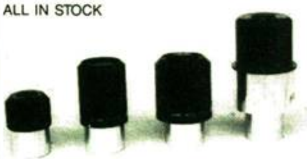

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| Renaissance 4" f/5.5. Telescope | $1450 |
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90° star diagonals with 96% reflectivity enhanced aluminum mirrors in a CNC machined black anodized aluminum body. Performance far exceeds prism diagonals.

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Tom Kramer saw the Owl Nebula, M-97, for the first time using a LUMICON UHC Filter. He stated, *"I had never seen M-97. . . I attached the UHC Filter and tried again. M-97 was right there. I could not believe it! The UHC Filter should be standard equipment."*

**Tom Kramer, Sayville, NY**

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# DEEP-SKY ASTROPHOTOGRAPHY

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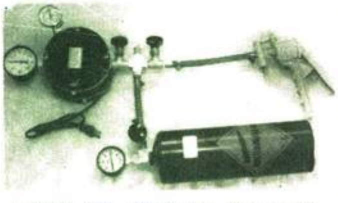

**MODEL 600 HYPER-KIT** (See photo) Like the Model 300, but also sensitizes 120/220 larger format film and small glass plates ..... **$350**

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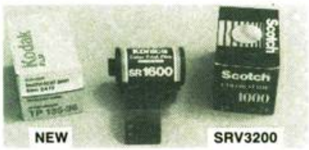

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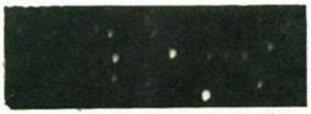
## COMA CORRECTOR



**Coma 1 inch off-axis 17½'' f/4.5**

**Same field with LUMICON coma corrector; smaller, more numerous stars.**

This computer-designed LUMICON 2" lens reduces coma and flattens the field for both viewing and photography. It threads into LUMICON 2" EASY-GUIDERS for effortless installation. This lens is optimized for f/4.5 and reduces aberrations for f/3.5 to f/5 Newtonians. Off-axis images are much smaller, making off-axis guiding far easier and yielding round pinpoint star images in photos. Since star images are sharp over a full 2¼" circle, you can use medium format cameras in addition to 35mm cameras. This zero power lens does not change image scale nor shift focus, and all lens surfaces are multi-coated for highest efficiency. Although designed for photography you may also use this lens to improve image quality in wide-field viewing with low power eyepieces.

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| LUMICON 2" EASY-GUIDER | **$169.50** |
| 2" EASY-GUIDER (Mamiya 645) | **$199.50** |
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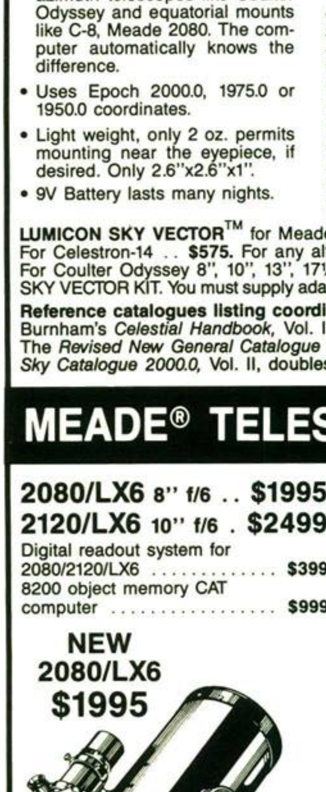

**Meade Model 2080/LX6:** The most advanced Schmidt-Cassegrain telescope available today. The hand-held electronic command center controls all telescope functions, and has digital coordinate readout available as an option. The f/6.3 optics yield 2½x shorter exposures in astrophotography.

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| 2080/LX3, 8" f/10 w/MCOG | **$1450** |
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| 2120/LX5, 10" f/10 w/MCOG | **$2095** |
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**1.8x Multiplier Lens**

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**LUMICON® LOW PROFILE FOCUSERS**

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| | |
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| **LUMICON 1¼'' Helical Focuser** | **$49.50** |
| **LUMICON 2'' Helical Focuser** | **$59.50** |
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| 2" rack & pinion low profile focuser | **$129.00** |
| 3 handles for non-rotating focuser | **$12.95** |
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| | |
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| 1¼" 50mm Finderscope **$59.50**, right-angle | **$89.50** |
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## 2'' ADAPTERS MEADE, CELESTRON TELESCOPES

These adapters convert refractors and Schmidt-Cassegrain telescopes for 2" operation. They allow use of 2" accessories, such as the LUMICON 2" EASY-GUIDER for photography. They also allow use of 2" eyepieces and/or 2" star diagonal for viewing.

| | |
|---|---|
| 2" adapter for C-8, Meade 2080, etc. | **$26.00** |
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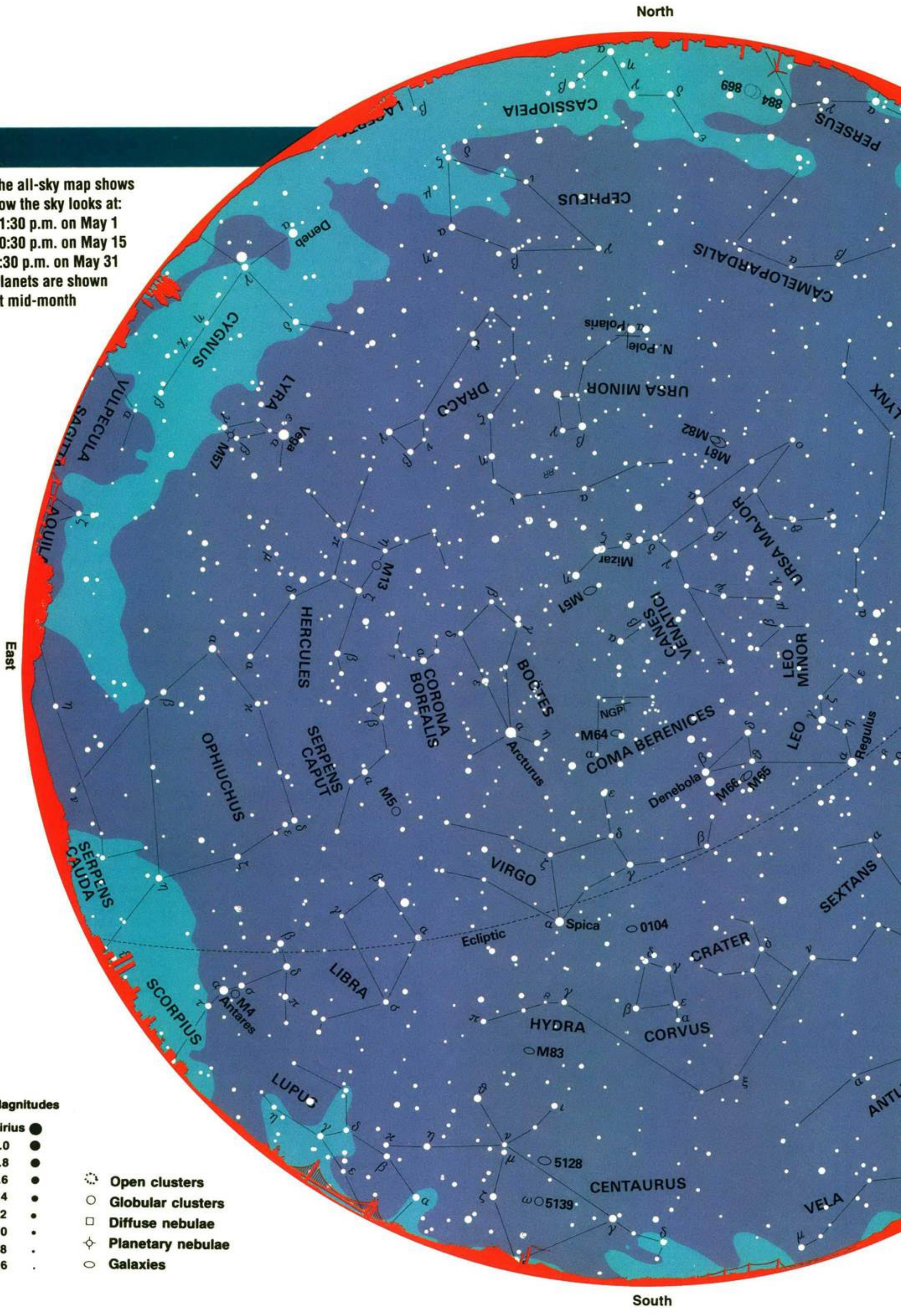
| 2" adapter for Takahashi E-130, 160 | **$59.50** |

The all-sky map shows how the sky looks at:
11:30 p.m. on May 1
10:30 p.m. on May 15
9:30 p.m. on May 31
Planets are shown at mid-month


North
CASSIOPEIA
PERSEUS
CEPHEUS
CAMELOPARDALIS
LACERTA
Deneb
CYGNUS
VULPECULA
SAGITTA
AQUILA
LYRA
Vega
M57
DRACO
Polaris
N. Pole
URSA MINOR
LYNX
M81
M82
URSA MAJOR
Mizar
M51
CANES VENATICI
LEO MINOR
HERCULES
M13
CORONA BOREALIS
BOÖTES
NGP
M64
COMA BERENICES
Arcturus
LEO
Regulus
Denebola
M66
M65
East
OPHIUCHUS
SERPENS CAPUT
M5
SERPENS CAUDA
VIRGO
SEXTANS
Spica
0104
Ecliptic
CRATER
LIBRA
SCORPIUS
M4
Antares
HYDRA
CORVUS
M83
LUPUS
ANTLIA
5128
CENTAURUS
5139
VELA
South

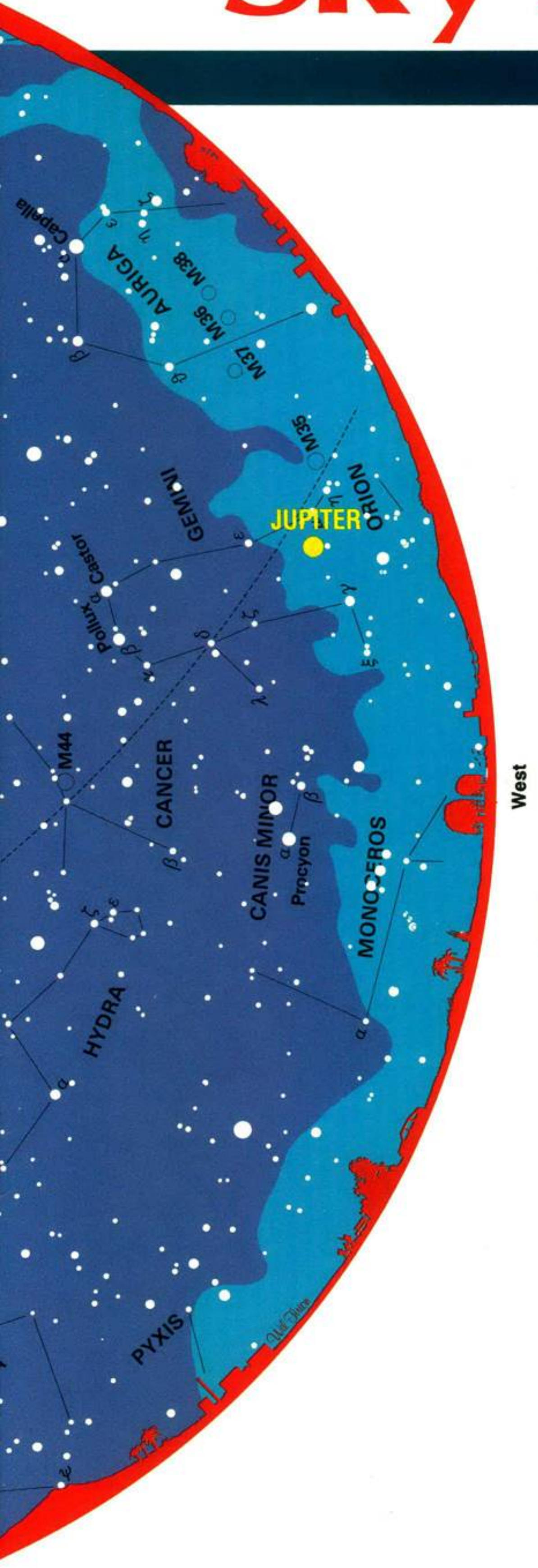
**Magnitudes**

Sirius ●
0.0 ●
0.8 ●
1.6 ●
2.4 •
3.2 •
4.0 •
4.8 ·
5.6 ·

◌ Open clusters
○ Globular clusters
□ Diffuse nebulae
✧ Planetary nebulae
⬭ Galaxies

# Sky Almanac

## May 1990



### COMET AUSTIN REMAINS BRIGHT

The brightest comet in several years rises well before the Sun in the east-northeast during the first week of May. In the second half of the month Comet Austin rises before midnight and is high in the south at daybreak.

### PLUTO AT ITS BRIGHTEST

Pluto is closer to Earth and brighter this month than at any other time in its 248-year orbit of the Sun. You can see the elusive ninth planet with an 8-inch or larger telescope among the background stars of Serpens Caput.

### ETA AQUARIDS PEAK ON MAY 5

The Eta Aquarid meteor shower peaks this year on the morning of May 5 and should join with Comet Austin to put on an exceptional show. Expect to see from ten to forty meteors per hour between the time the Moon sets and twilight begins.

### SEARCH FOR A VERY YOUNG MOON

You may be able to spot an extremely thin crescent Moon on the evening of May 24. Use binoculars and scan very near the west-northwest horizon about thirty minutes after sunset.

## Dates and Times

**1** First Quarter Moon is at 4:18 p.m. EDT

**3** Mercury is in inferior conjunction

**4** Saturn is stationary

**5** Eta Aquarid meteor shower peaks

**7** Pluto is at opposition
Juno is at opposition

**9** Full Moon is at 3:31 p.m. EDT
The Moon is at apogee (252,545 miles from Earth), 8:18 p.m. EDT

**11** The Moon passes 0.2° north of Antares, 9 a.m. EDT

**13** Iris is at opposition

**15** The Moon passes 1.5° south of Saturn, 4 a.m. EDT

**17** Last Quarter Moon is at 3:45 p.m. EDT

**19** Comet Schwassmann-Wachmann 3 is at perihelion

**23** The Moon is at perigee (222,040 miles from Earth), 11:02 p.m. EDT

**24** New Moon is at 7:47 a.m. EDT

**25** Pallas is in conjunction with the Sun

**26** The Moon passes 2° north of Jupiter, 10 p.m. EDT

**30** Mercury is at greatest western elongation (25°)

**31** First Quarter Moon is at 4:11 a.m. EDT

## COMET AUSTIN CLIMBS HIGHER IN THE SKY

Comet Austin continues to be an impressive sight during May. Your best view of it should come early in the month when the comet is nearly as bright as it was in late April and the Moon is out of the sky. Look for Austin shortly before dawn when it is well-placed in the east-northeast above the Great Square of Pegasus. It rises earlier, and thus appears higher in the sky as twilight approaches, with each passing day.

To see the comet well you need to leave the lights of the city far behind. Choose an observing site with a dark sky and a clear view of the northeast horizon. The comet rises over that horizon about three hours before twilight begins in early May. Expect Austin to look like a fuzzy star with a tail pointing slightly to the right of a line perpendicular to the horizon.

The nearly full Moon floods the morning sky with light after the first week of May, seriously interfering with the view. By May 15, however, Comet Austin is rising before the Moon does and you can observe it once again. The comet rises in the northeast around midnight on the 15th and progressively earlier each day after. Austin passes closest to Earth around May 25 when the Moon is out of the sky all night. It then fades rapidly as it heads back toward the outer solar system. (For more details on observing Comet Austin, see "Get Ready for Comet Austin," April 1990.)

## A FINE SPRING METEOR SHOWER

It's exciting when a bright comet appears in our sky, but the excitement is usually short-lived. Comets are temporary visitors to Earth's vicinity; as they pursue their long orbits around the Sun, they soon disappear. Some comets, however, leave behind a legacy of their trip through the inner solar system: an annual meteor shower.

Each May observers can see meteors spawned by the most famous comet of all, Comet Halley. The Eta Aquarid meteor shower, named for a star in the "Water Jar" asterism of the constellation Aquarius near where the meteors appear to radiate, peaks this year on the morning of May 5. You can expect to see from ten to forty meteors per hour that morning and perhaps half that number on the mornings of the 4th and 6th. A typical Eta Aquarid meteor races across the sky at 40 miles per second and leaves a long, glowing trail.

As with all meteor showers, you will get the best view of the Eta Aquarids from a dark-sky site. Observe after 3:30 a.m. daylight time when the waxing gibbous Moon sets. For the next hour or so you should get a great view of both Comet Austin and the meteors left behind by Comet Halley.

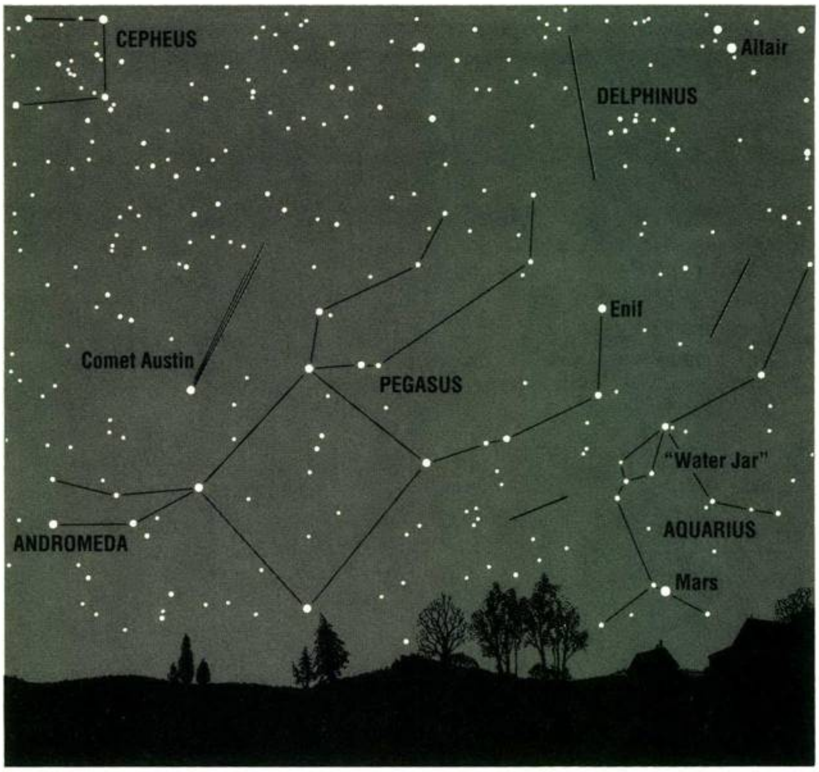
**THE SLIM CRESCENT** of a one-day-old Moon hangs low in the sky in Ivan Dryer's April 1989 photo. On the evening of May 24 observers may be able to see an even younger Moon just above the west-northwestern horizon after sunset.

## CAN YOU SPOT A RECORD-SETTING YOUNG MOON?

Last month many of you saw a very slender crescent Moon hanging low in the west-northwest after sunset on April 25. That evening the Moon was about 20 hours old as seen from the East Coast of North America and 23 hours old as seen from the West Coast. On May 24 observers have a chance to spot an even younger Moon, and from the East Coast perhaps spot the youngest Moon ever seen.

New Moon occurs at 7:47 a.m. EDT on May 24. On the East Coast the Sun sets a bit over twelve hours later, and half an hour after that the slimmest of crescent Moons might appear briefly in the bright twilight sky before the Moon sets. The Moon becomes progressively easier to see the farther west you live, but even from the West Coast the 16-hour-old Moon will be an observing challenge.

Unlike last month, when the young Moon was higher in the sky and many viewers were able to see it with the naked eye, you'll need binoculars to see the Moon on May 24. Begin scanning just above the horizon between west-northwest and northwest thirty minutes after sunset.



**COMET AUSTIN AND METEORS** combine to make the morning of May 5 special. Look to the east in the hour before twilight begins for your best view of both the comet and the Eta Aquarid meteor shower.

## MAY'S PLANETS

The first starlike object you'll see in the west after sunset is brilliant Jupiter. Shining at magnitude –1.9, the king of planets is impossible to miss. It is particularly appealing on the evening of May 26, when the waxing crescent Moon lies 2° away.

Jupiter remains in Gemini this month, slowly edging closer to that constellation's brightest stars, Castor and Pollux. It will appear closest to these stars in late summer and early autumn, after it has passed behind the Sun and reappeared in the predawn sky.

Saturn is the next bright planet to appear after Jupiter, though it doesn't rise until around midnight. The ringed planet shines at magnitude 0.4 and lies east of the conspicuous Teapot asterism in Sagittarius. On the morning of May 15 Saturn is joined by the gibbous Moon, which passes just 1.5° south of it.

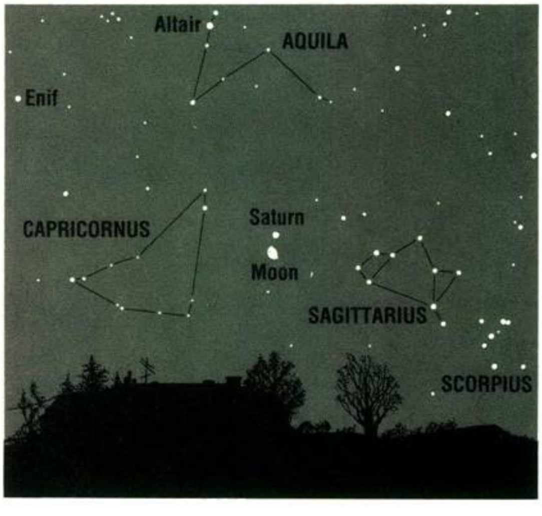
Mars, the most changeable planet in appearance, is still relatively inconspicuous in our sky. It rises between two and three hours before the Sun and stands low in the southeast at sunrise, shining at magnitude 0.7.

The Red Planet may not be eye-catching now, but just wait. In November, when Earth passes between Mars and the Sun, it will appear very different. Mars will then shine at magnitude –2.0, its brightest in over two years, and outshine all the stars and most of the planets.

Brilliant Venus shines at magnitude –4.1 in May, by far the brightest object in the sky besides the Sun and Moon. It lies 20° to the lower left of Mars in the predawn sky at the beginning of the month and 30° from the Red Planet by month's end, though you're much more likely to find Mars using Venus as a guide than the other way around.

Innermost Mercury passes between the Sun and Earth on May 3, a configuration known as inferior conjunction. After that Mercury lives up to its name — the fleet-footed messenger god of ancient myths — and races into the morning sky. On May 30/31 the planet reaches greatest elongation, when it lies 25° west of the Sun. Unfortunately,

**SATURN AND THE MOON** lie halfway between Sagittarius and Capricornus and only 1.5° apart on the morning of May 15. Look for the pair in the south as twilight begins.



this is an unfavorable elongation for Mercury. You'll be hard-pressed to see it without binoculars.

## *MAY'S STARRY SKY*

During my first year of learning the names of the stars and constellations, I spent a great deal of time poring over charts and books. While most people see a star in the sky, wonder about its name, and afterwards look it up, in my enthusiasm I often did just the opposite. I knew the names of the stars beforehand and eagerly awaited my first look at them.

That was the case when I first saw Vega, the brightest star in the constellation Lyra, the Lyre, and the fifth brightest star in the sky. One May evening many years ago I was out walking and happened to glance toward the northeastern horizon. A gleaming, sapphire-blue star met my gaze. It seemed surprisingly bright for being so low in the sky. What a rush of discovery! Vega!

Vega has always been beautiful, but how could we know it would also become one of the most tantalizing stars in the sky? This star is one of several that emit an unusual amount of infrared radiation, which indicates that it is surrounded by a disk of dust particles. These particles are not in themselves a solar system, but they hint that the process we believe forms planets may be at work around Vega.

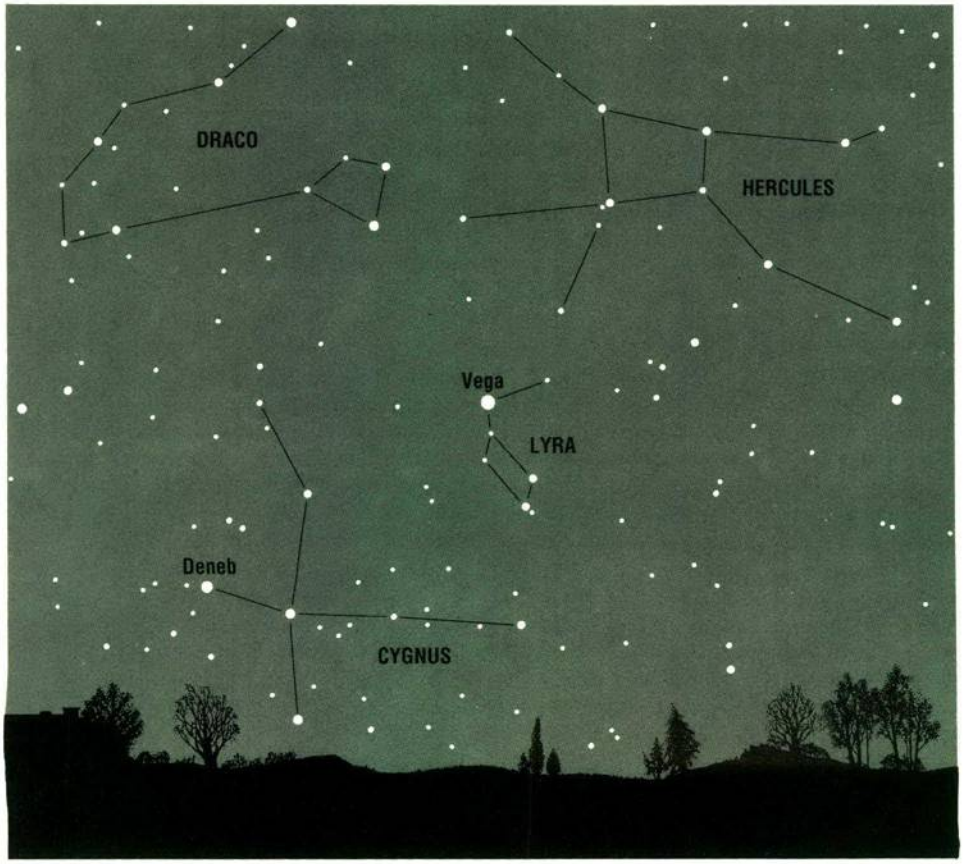
Vega is easy to find this month low in the northeast after nightfall. And once you've found Vega, Lyra's distinctive shape is easy to recognize. The main part of the small and compact constellation consists of Vega and five fainter stars. Four of these stars form a parallelogram to the southeast of Vega and the fifth makes a triangle with Vega and the nearest of the other stars.

In Greek mythology Lyra represents the lyre or harp of the musician Orpheus. It was said that this instrument was fashioned from a tortoise shell. When Orpheus played it, neither mortal nor god could turn away.

The Chinese also have a myth about Lyra, which is still told today. In it, Vega represents the Spinning Damsel, really a god who was sent to Earth for a short time. There she became the wife of a deserving man, who loved her dearly. She bore him a son but could not stay with him because gods are not permitted to stay on Earth for long.

She returned to heaven where she can be seen seated at her loom, weaving tapestries fit for the gods. She resides on the western edge of the Great River in the sky, otherwise known as the starlit trail of the Milky Way. Her husband can be seen on the opposite side of this river, as the star Altair in the constellation Aquila. Once each year, on the seventh night of the seventh moon, a bridge of magpies spans this river in the sky so the lovers can be reunited.

**VEGA SHINES BRILLIANTLY** in the northeast on May evenings, showing the way to its small, yet distinctive, constellation, Lyra.



## *Through the Eyepiece by Rick Shaffer*

### *HOW BRIGHT IS COMET AUSTIN?*

Comet Austin continues its excellent morning apparition in May, shining at 2nd or 3rd magnitude. Rising earlier and climbing steadily higher throughout the month, Austin should be an easy target whenever the Moon is out of the sky. (See "Get Ready for Comet Austin," April 1990.)

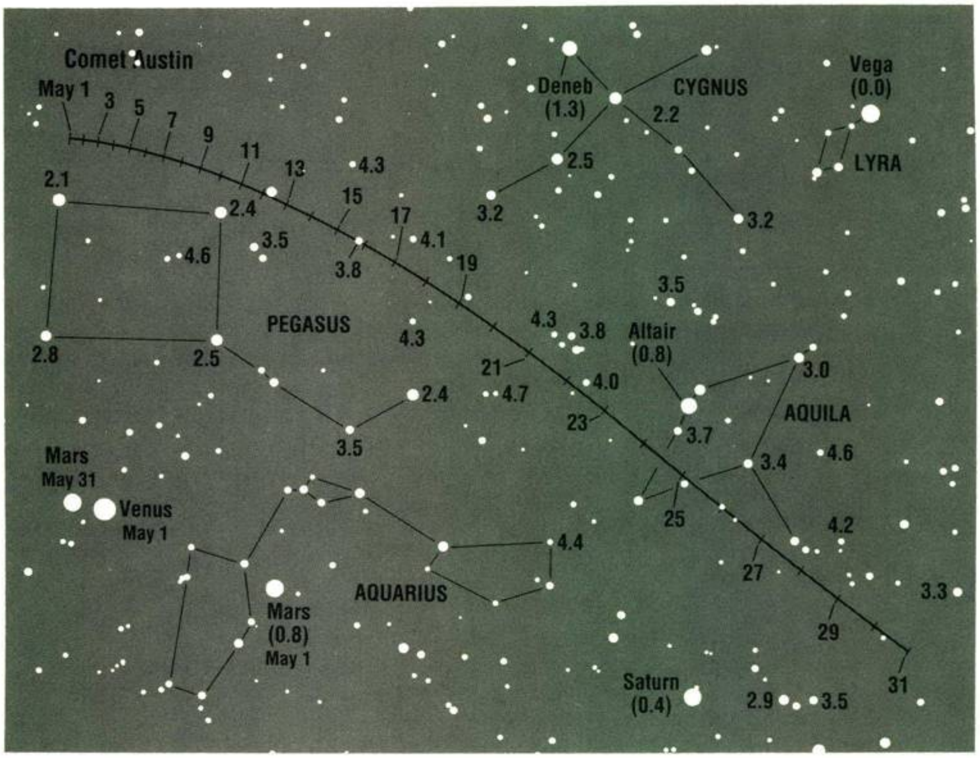
The first Moon-free observing period this month runs from April 25 to May 7. On May 1 Austin rises around 2 a.m. daylight time and lies 25° above the east-northeastern horizon at the beginning of morning twilight. The second Moon-free period begins on May 15 and runs through the end of the month. On the 15th look for the comet to rise from the northeast horizon around midnight daylight time; on the 31st the comet rises in the east-southeast in early evening and is high in the south at daybreak.

However, you don't need to confine your viewing of the comet to times when the Moon is absent. The Moon does its greatest harm to low-power views of the comet's tail. But you can observe the comet's coma at high powers with relative impunity even when the Moon is quite bright.

A high-power view of Austin's coma may show what appear to be streamers of light. These are jets, local pockets of ice that suddenly erupt from just below the surface of the comet's nucleus. They can change appearance radically from day to day and even hour to hour.

Low-power views of Austin's coma are just as important to understanding the comet because that is how astronomers determine its brightness. As we go to press with this issue in mid-February, Comet Austin had brightened at least as much, if not more than, many astronomers had predicted. This doesn't necessarily mean Austin will be brighter than 2nd magnitude in May or even that it will be that bright, but it is an encouraging sign.

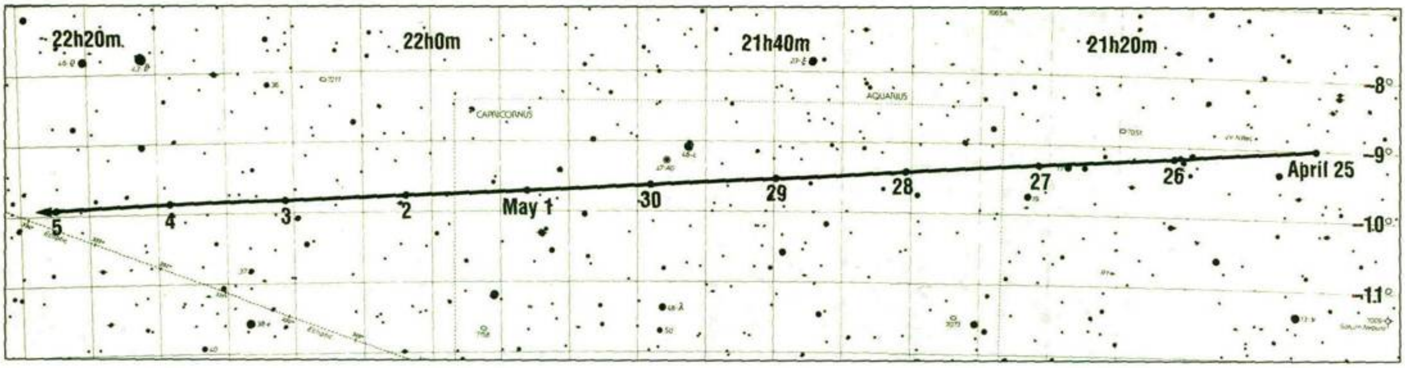
You can compare the comet's actual brightness with its predicted brightness throughout the month by regularly estimating the comet's magnitude. The technique is to compare the comet's brightness with that of several nearby comparison stars. (The magnitudes of many suitable stars are given in the diagram above.) In one common method you start by viewing the comet through binoculars or a low-power eyepiece. Estimate the size of the comet's coma and the coma's average brightness and commit them to memory. Then swing your telescope to a nearby star having a similar magnitude and deliberately defocus the star's image until it is the same apparent size as the in-focus image of the comet. If the star appears brighter or dimmer than the comet, select a slightly dimmer or brighter comparison star, respectively, and repeat the process. Repeat this process until you can't notice a difference between the star's brightness and the comet's brightness, or until you can confidently interpolate the comet's brightness between those of two stars. The comet's magnitude is the same as that of the matching star.



**ESTIMATE AUSTIN'S MAGNITUDE** by comparing the comet's brightness to that of nearby stars. Positions are shown at 4 a.m. EDT (3 a.m. CDT, 2 a.m. MDT, and 1 a.m. PDT).

**COORDINATES FOR COMET AUSTIN**

| Date | R.A. (2000) | Dec. |
|---|---|---|
| May 1 | 0h05.4m | 35°45' |
| May 3 | 23h53.5m | 35°17' |
| May 5 | 23h40.8m | 34°37' |
| May 7 | 23h27.1m | 33°42' |
| May 9 | 23h12.0m | 32°31' |
| May 11 | 22h55.4m | 30°59' |
| May 13 | 22h36.7m | 29°01' |
| May 15 | 22h15.8m | 26°29' |
| May 17 | 21h52.2m | 23°15' |
| May 19 | 21h26.0m | 19°11' |
| May 21 | 20h57.1m | 14°11' |
| May 23 | 20h26.1m | 8°20' |
| May 25 | 19h53.9m | 1°55' |
| May 27 | 19h21.6m | –4°35' |
| May 29 | 18h50.4m | –10°38' |
| May 31 | 18h21.5m | –15°52' |



**COMET SCHWASSMANN-WACHMANN 3** is a 9th-magnitude object in the morning sky in late April and early May. Positions are shown at 5 a.m. EDT (4 a.m. CDT, 3 a.m. MDT, and 2 a.m. PDT). Adapted from *Uranometria 2000.0*, ©1987 Willmann-Bell, Inc.

**COORDINATES FOR COMET SCHWASSMANN-WACHMANN 3**

| Date | R.A. (2000) | Dec. |
|---|---|---|
| April 25 | 21h08.7m | –9°02' |
| April 28 | 21h32.2m | –9°25' |
| May 1 | 21h54.5m | –9°42' |
| May 4 | 22h15.4m | –9°52' |
| May 7 | 22h34.9m | –9°56' |
| May 10 | 22h53.1m | –9°54' |
| May 13 | 23h10.0m | –9°48' |
| May 16 | 23h25.7m | –9°37' |
| May 19 | 23h40.4m | –9°24' |
| May 22 | 23h54.0m | –9°08' |
| May 25 | 0h06.7m | –8°49' |
| May 28 | 0h18.7m | –8°29' |
| May 31 | 0h29.8m | –8°08' |

Although making magnitude estimates is fun in its own right and is a good way to develop observing skills, you can also use your estimates to help astronomers develop a light curve for Comet Austin. Send your observations to Don Machholz, A.L.P.O. Comets Section Recorder, 5234 Camden Avenue, San Jose, CA 95124. It's best to write Don beforehand to request a report form. (Include a self-addressed, stamped envelope.) This form lists all the information you need to include, such as the date and time of the observation, your equipment, the size and shape of the coma, the length and direction of the tail, and your observing site and the observing conditions.

## *A SECOND, FAINTER COMET*

Although Comet Austin should occupy most of your early-morning observing time this month, there's a second comet worth viewing in the morning sky. Periodic Comet Schwassmann-Wachmann 3 (S-W 3) lies roughly 40° south of Austin and should shine around 9th magnitude in early May. S-W 3 was discovered in 1930 by German astronomers A. Schwassmann and A. A. Wachmann. Despite having a period of slightly more than five years, it has been seen at only one apparition since then, in 1979. That's because its orbit generally keeps it hidden in the Sun's glare when it is brightest. However, the 1990 return of the comet is the best since 1930. S-W 3 should be fairly easy to see this time around.

The best time to search for S-W 3 is shortly before morning twilight begins during the last week of April and the first week of May. Use the finder chart or table of coordinates on this page to follow the comet as it moves from Aquarius into extreme northern Capricornus and back into Aquarius. Although S-W 3 won't be anywhere near as spectacular as Comet Austin, it gives you the chance to compare the appearance of a bright comet making its first known voyage through the inner solar system with a relatively faint, short-period comet that has rarely been seen. I hope you manage to make May a two-comet month!

## *PLUTO REACHES OPPOSITION (WITH JUNO NEARBY)*

Our solar system's smallest and most unusual planet, Pluto, is at opposition on the night of May 6/7. On that date it is at its closest to Earth not only for this year, but for any time in its 248-year orbit of the Sun. And because Pluto is closest to us, it's also brightest, though I hesitate to call a 13.6-magnitude object bright. Still, the elusive planet won't be as easy to see again until the twenty-third century, so there's no better time than right now to take up the observing challenge.

To find Pluto you need an 8-inch or larger telescope and a dark-sky observing site. Use the chart on page 49 to locate Pluto's starfield in southwest Serpens Caput, and then zoom in on the region with a medium-power eyepiece. (The brightest star in the area is SAO 140392, a 6.6-magnitude star.) The chart shows stars down to magnitude 16.0, so you may well be able to identify Pluto right at the eyepiece. To confirm your identification, however, it's best to photograph or sketch the starfield and then repeat the observation a night or two later. The 14th-magnitude "star" that moves is Pluto.

Under most circumstances it would be best to observe Pluto in the latter part of May when the Moon is out of the sky. But due to an extraordinary coincidence you may want to search for the planet on the evenings of May 10 to 13, just after the Full Moon. On those days one of the largest and brightest asteroids, 3 Juno, passes just south of Pluto, providing a rare opportunity to see both Pluto and an asteroid in the same field of view. The two are closest on the night of May 11/12 when 10th-magnitude Juno lies only 20' from Pluto.

## *TELESCOPIC PLANETS*

Mercury appears in the morning sky in the second half of May. The innermost planet reaches greatest elongation on May 30/31, when it lies 25° west of the Sun. Unfortunately, this is not a favorable apparition for Mercury. At greatest elongation it is only 5° above the eastern horizon thirty minutes before sunrise. If you make the effort to observe Mercury on the morning of its elongation, you'll find a 39-percent-lit crescent measuring 8" across that shines at magnitude 0.5.

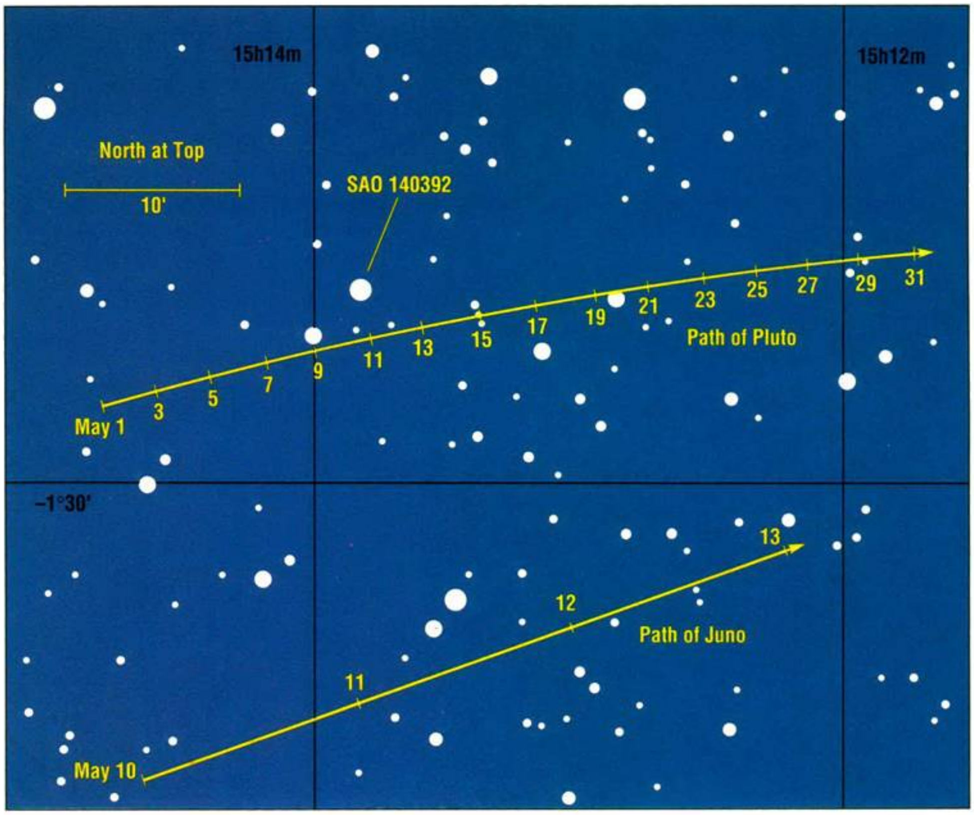
Venus is in a similar plight, although because it is much brighter it is much easier to see in the morning twilight. The –4.1-magnitude planet shows a 69-percent-lit gibbous phase at midmonth and measures 16" across.

While Venus has been shrinking in apparent size over the past few months, Mars has been growing larger in the morning sky. Unfortunately the progress has been slow: the 0.7-magnitude Red Planet remains less than 7" in diameter. If you want to see more than the planet's polar caps, however, you'll need to wait for a night of excellent seeing, or until late this summer when Mars appears significantly larger.

May is the last good month to observe Jupiter for a while. The planet sets more than four hours after the Sun at the beginning of the month and is still reasonably high in the sky as darkness falls, but by the end of the month it sets only two hours after the Sun and is low in the twilight sky. Use the early evening hours to see whether the Great Red Spot is continuing to darken and if any changes are brewing in Jupiter's South Equatorial Belt. The 34"-diameter planet shines at magnitude –1.9 in May.

Saturn is quickly approaching its July opposition and is now becoming well-placed for telescopic viewing. The ringed planet rises around midnight in mid-May and is on the meridian at sunrise. If you've been up observing Comet Austin in the morning, it's worth turning your telescope on Saturn to take advantage of the often steady atmosphere during twilight. The 0.4-magnitude planet has a disk 17" in apparent diameter and a ring system that spans 40" this month.

Uranus and Neptune continue to keep Saturn company in the morning sky. Uranus is a blue-green world that shines at magnitude 5.6 in May and measures 3.7" in diameter. Neptune is somewhat smaller and fainter than Uranus, with a 2.3"-diameter disk shining at magnitude 7.9, and has a blue-gray color when seen through a telescope. ☐



**FIND PLUTO IN MAY** as it reaches opposition near the asteroid Juno. Positions of the objects are shown at 10 p.m. PDT (11 p.m. MDT, midnight CDT, and 1 a.m. EDT the following morning). Map courtesy Doug Mink, Center for Astrophysics.

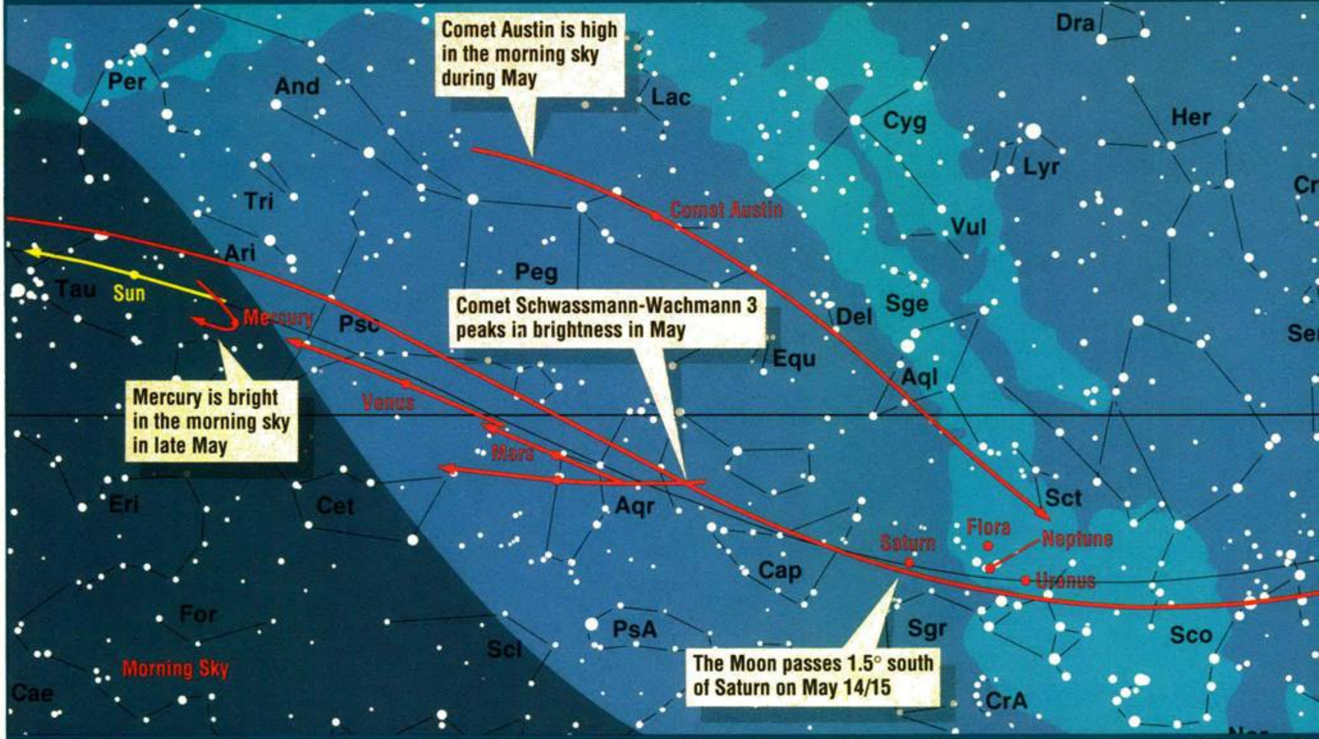
### COORDINATES FOR PLUTO

| Date | R.A. (2000) | Dec. |
|---|---|---|
| May 1 | 15h14m50s | –1°26'28" |
| May 3 | 15h14m38s | –1°25'36" |
| May 5 | 15h14m25s | –1°24'46" |
| May 7 | 15h14m13s | –1°23'59" |
| May 9 | 15h14m00s | –1°23'13" |
| May 11 | 15h13m48s | –1°22'30" |
| May 13 | 15h13m35s | –1°21'49" |
| May 15 | 15h13m22s | –1°21'10" |
| May 17 | 15h13m10s | –1°20'34" |
| May 19 | 15h12m57s | –1°20'01" |
| May 21 | 15h12m45s | –1°19'31" |
| May 23 | 15h12m33s | –1°19'03" |
| May 25 | 15h12m20s | –1°18'38" |
| May 27 | 15h12m08s | –1°18'15" |
| May 29 | 15h11m56s | –1°17'56" |
| May 31 | 15h11m45s | –1°17'39" |

### COORDINATES FOR JUNO

| Date | R.A. (2000) | Dec. |
|---|---|---|
| May 9 | 15h15m29s | –1°52'02" |
| May 10 | 15h14m40s | –1°47'22" |
| May 11 | 15h13m51s | –1°42'49" |
| May 12 | 15h13m02s | –1°38'22" |
| May 13 | 15h12m13s | –1°34'04" |
| May 14 | 15h11m25s | –1°29'52" |

# The Solar System May 1990

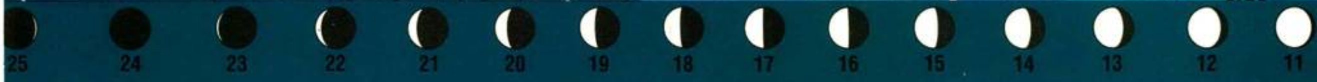

Per
And
Lac
Dra
Cyg
Her
Lyr
Cr
Tri
Comet Austin
Vul
Ari
Peg
Tau
Sun
Mercury
Psc
Del
Sge
Ser
Equ
Aql
Venus
Mars
Sct
Eri
Cet
Aqr
Flora
Neptune
Saturn
Cap
Uranus
For
Sgr
Sco
PsA
Scl
Morning Sky
Cae
CrA

Comet Austin is high in the morning sky during May

Comet Schwassmann-Wachmann 3 peaks in brightness in May

Mercury is bright in the morning sky in late May

The Moon passes 1.5° south of Saturn on May 14/15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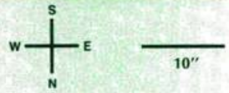
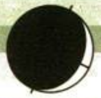
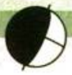
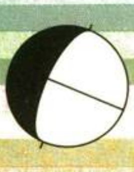
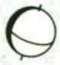




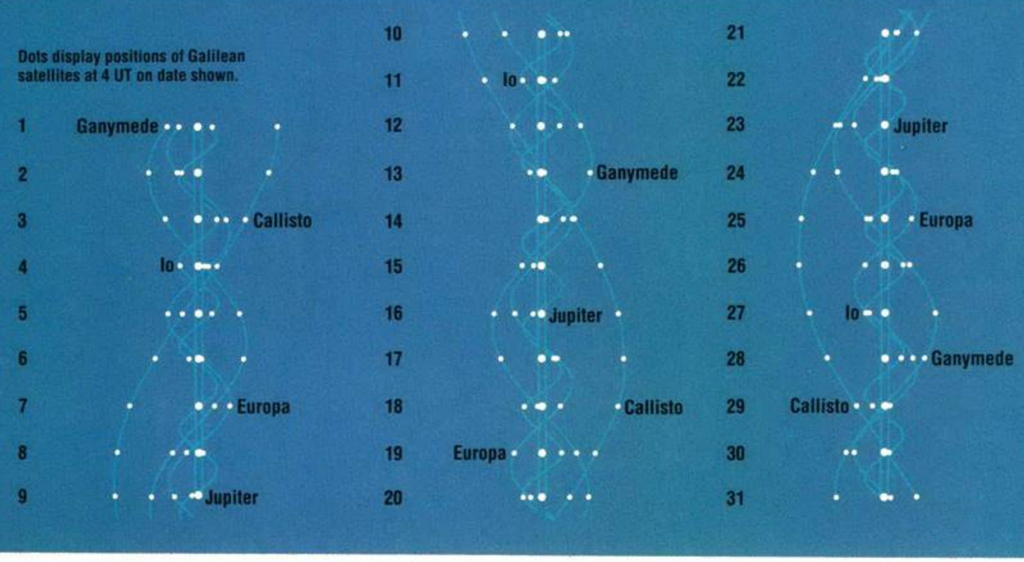




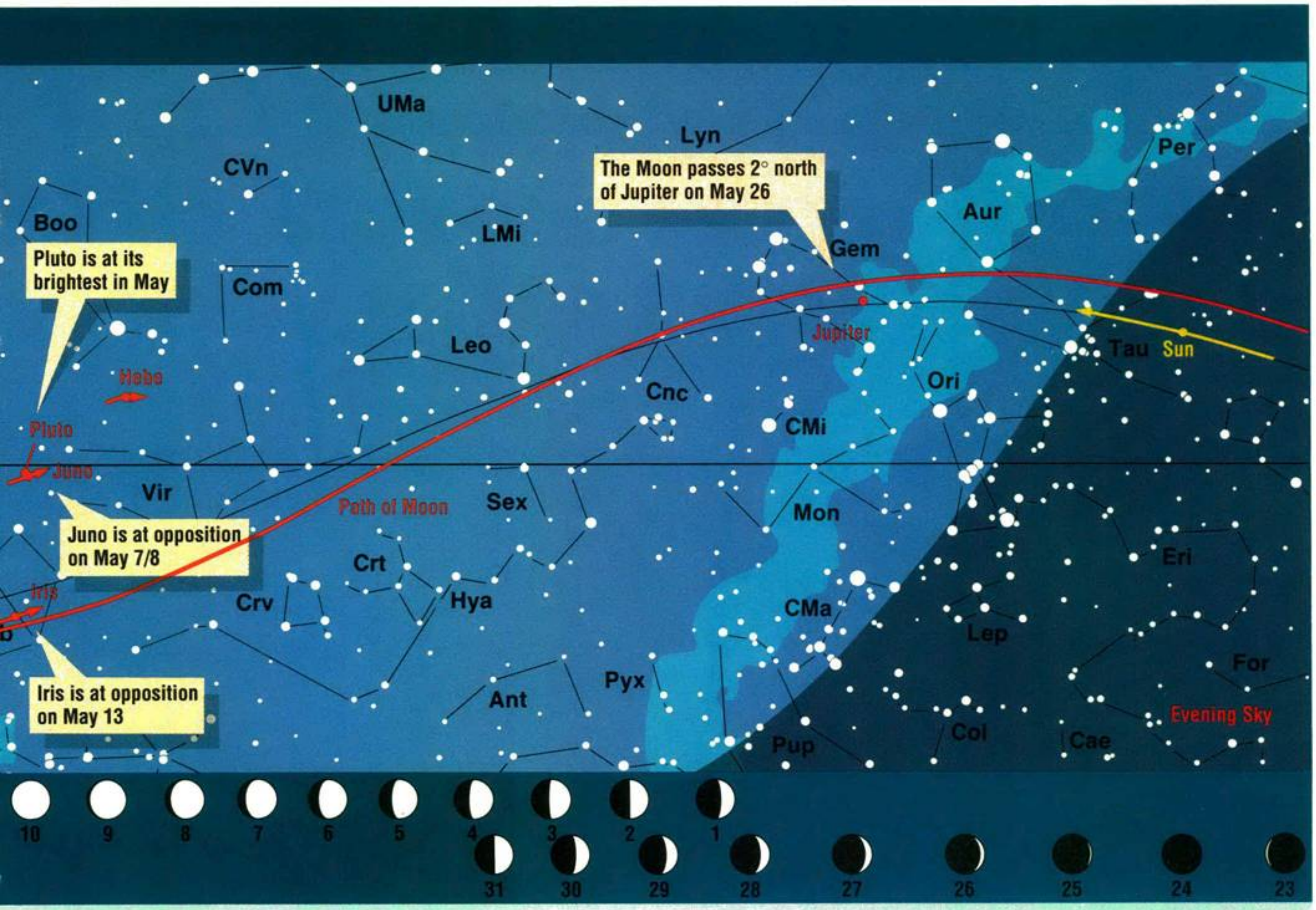


| Planet | MERCURY | MERCURY | VENUS | MARS |
|---|---|---|---|---|
| Date | May 15 | May 31 | May 15 | May 15 |
| Magnitude | +2.5 | +0.6 | –4.1 | +0.7 |
| Angular Size | 11.3" | 8.2" | 16.1" | 6.4" |
| Illumination | 10% | 38% | 69% | 88% |
| Distance (AU) from Earth | 0.598 | 0.817 | 1.034 | 1.460 |
| Distance (AU) from Sun | 0.467 | 0.436 | 0.728 | 1.397 |
| Right Ascension (2000.0) | 2h26.6m | 2h54.4m | 0h48.3m | 23h18.9m |
| Declination (2000.0) | 11°57′ | 12°56′ | 3°15′ | –6°18′ |

## Jupiter's Moons



Dots display positions of Galilean satellites at 4 UT on date shown.

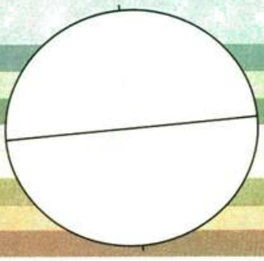

UMa
Lyn
CVn
Boo
LMi
Gem
Aur
Per
Com
Leo
Jupiter
Tau
Sun
Hebe
Cnc
Ori
Pluto
CMi
Juno
Vir
Path of Moon
Sex
Mon
Eri
Crt
Crv
Hya
Iris
CMa
Lep
For
Pyx
Ant
Col
Cae
Evening Sky
Pup
10 9 8 7 6 5 4 3 2 1
31 30 29 28 27 26 25 24 23

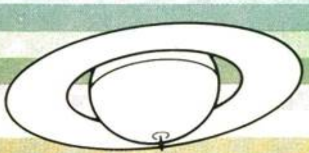
The Moon passes 2° north of Jupiter on May 26

Pluto is at its brightest in May

Juno is at opposition on May 7/8

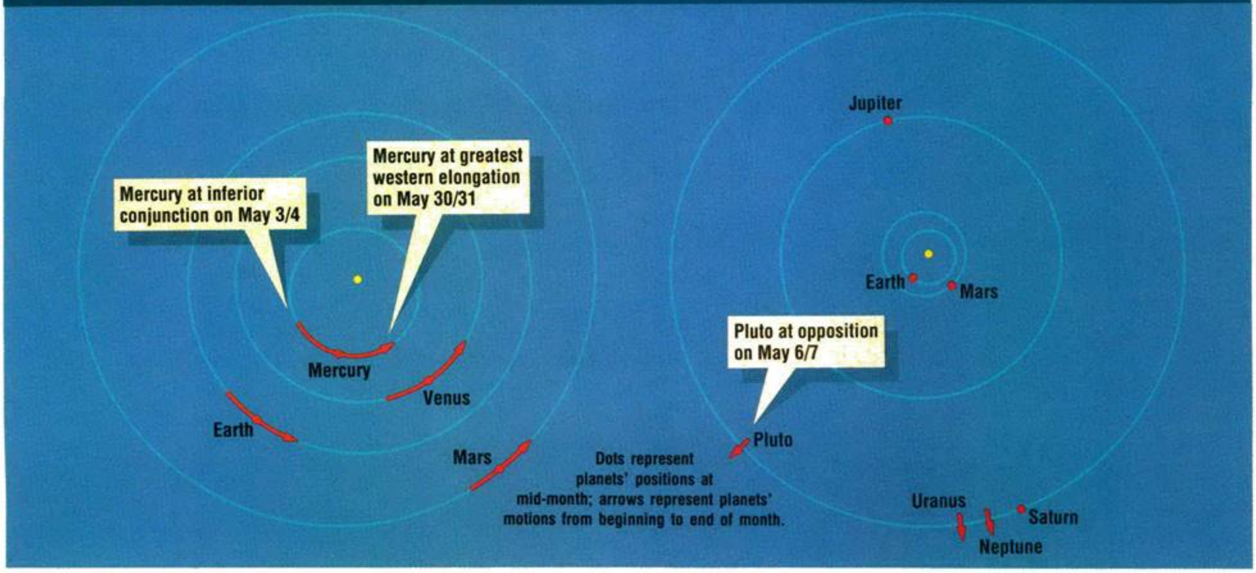
Iris is at opposition on May 13





| | JUPITER | SATURN | URANUS | NEPTUNE | PLUTO |
|---|---|---|---|---|---|
| | May 15 | May 15 | May 15 | May 15 | May 15 |
| | −1.9 | +0.4 | +5.6 | +7.9 | +13.6 |
| | 33.6" | 17.4" | 3.7" | 2.3" | 0.1" |
| | 100% | 100% | 100% | 100% | 100% |
| | 5.857 | 9.492 | 18.679 | 29.554 | 28.694 |
| | 5.199 | 10.016 | 19.404 | 30.207 | 29.659 |
| | 6h41.7m | 19h49.3m | 18h40.7m | 19h02.5m | 15h13.5m |
| | 23°14' | −20°55' | −23°26' | −21°47' | −1°22' |

## The Planets in Their Orbits


Mercury
Venus
Earth
Mars
Jupiter
Earth
Mars
Pluto
Uranus
Saturn
Neptune

Mercury at inferior conjunction on May 3/4

Mercury at greatest western elongation on May 30/31

Pluto at opposition on May 6/7

Dots represent planets' positions at mid-month; arrows represent planets' motions from beginning to end of month.

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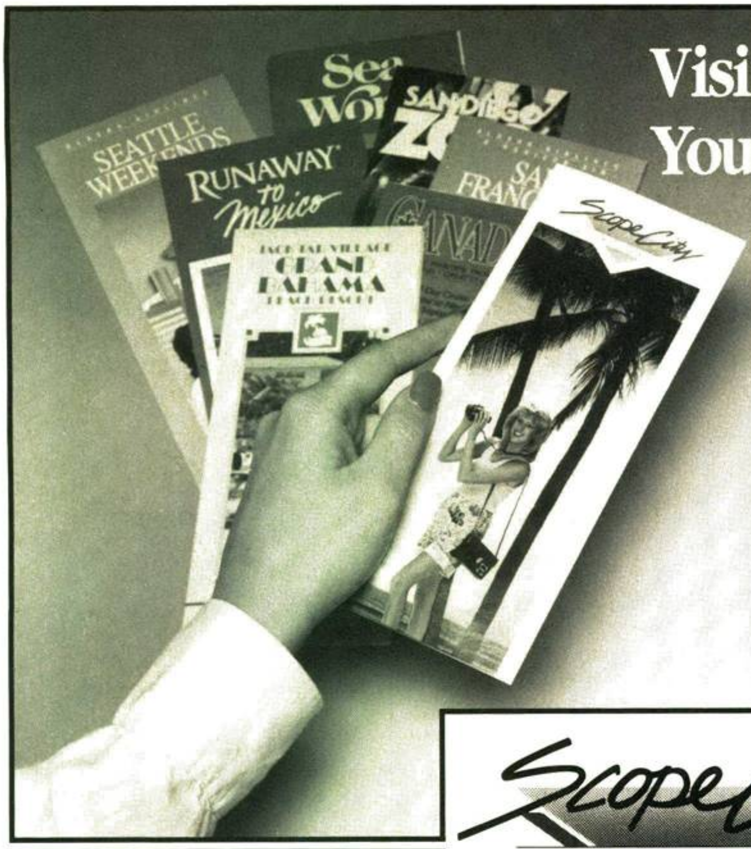

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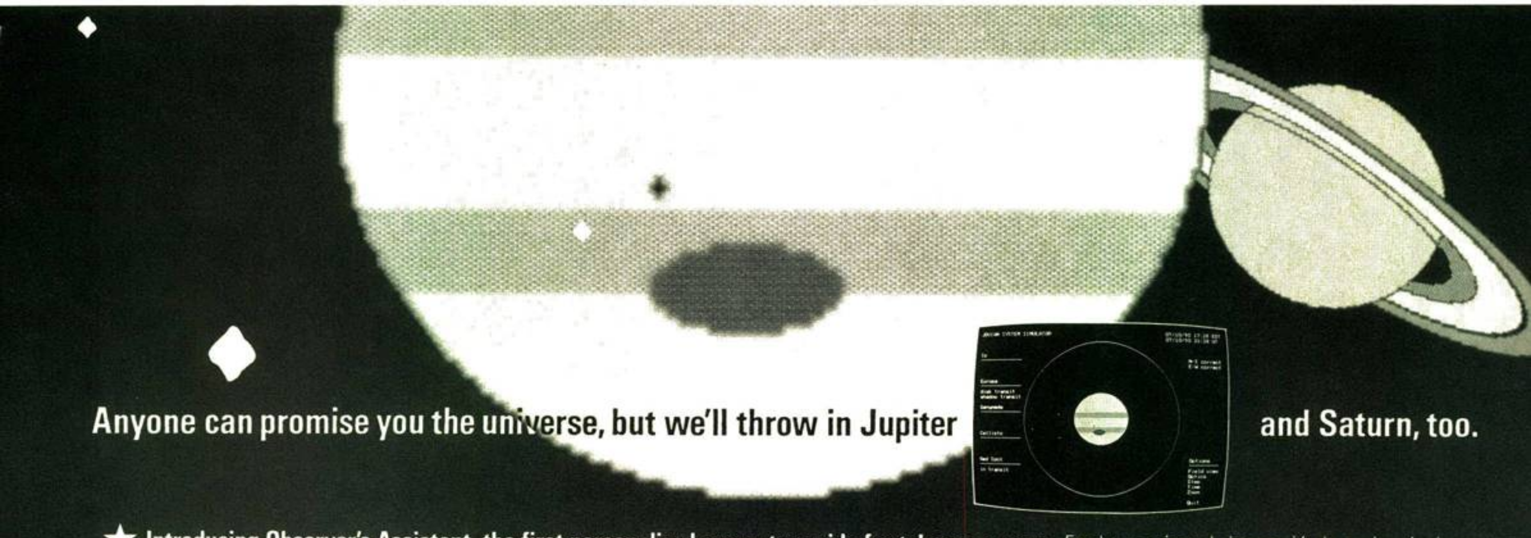

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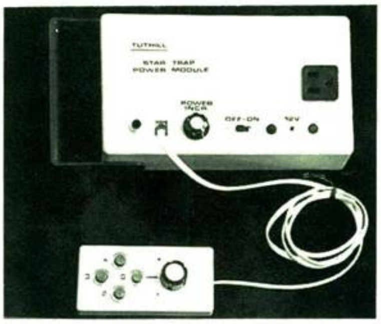

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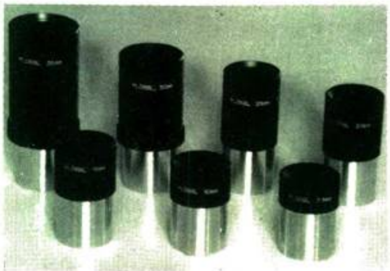

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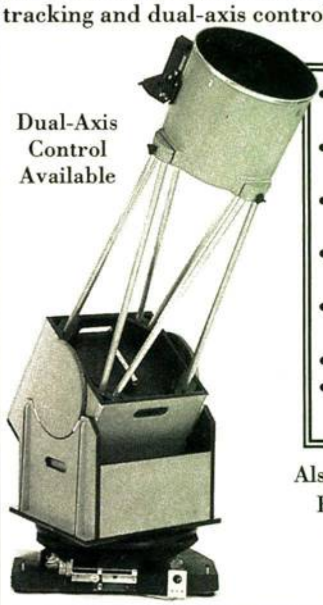

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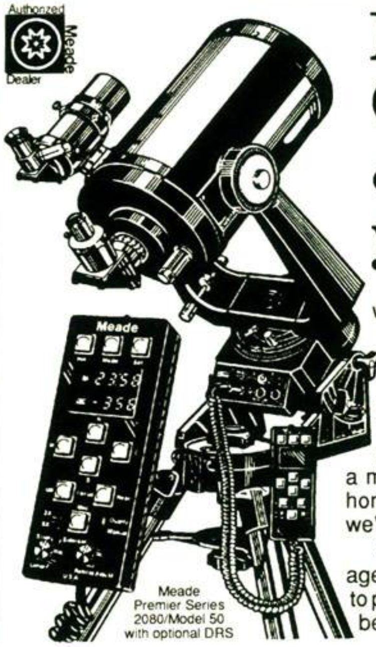

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# Test Drive Your Telescope

Ever wonder if your telescope's optics are performing as well as they should? These simple tests will let you find out.

by Dick Suiter

If you're a typical amateur astronomer, chances are you're more interested in the views you get through your telescope than in how those images are made. A telescope and its optics are something you buy. They are not the whole point of your hobby. But have you ever wondered whether your telescope is delivering the image quality it's supposed to?

With many consumer goods it's easy to tell when there's a manufacturing defect. If you bought a new car and it only went 10 miles an hour, you would know something was wrong. But how can you tell when a telescope has a problem? How can you be sure the telescope's optics are performing as well as they should? These are important questions when buying any type of telescope — used, homemade, or units straight from the factory.

I've found that manufacturers want to deliver a quality product, but with the large number of telescopes being produced, some bad instruments slip through. Most manufacturers I've dealt with were more than willing to overcome any problems with optics, when they finally saw that there indeed was a problem. This is where it pays for you as a consumer to be able to tell good optics from poor optics.

Fortunately, there is a simple but very sensitive method for testing the quality of your optics, one that requires no special equipment. Just as you don't have to know the theory of the internal combustion engine to know that your car isn't running right, you don't have to understand optical design theory to check telescopes. With some experience in applying these techniques, you can become an informed judge of optical quality.

### The Perfect Star Image

The first step in evaluating optics is to establish a test standard to serve as a basis for comparison. You need to know what a perfect star image looks like. You might expect that the star images produced by a perfect telescope would be crisp, sharp-edged points of light. They aren't. At high power a star appears as a tiny disk with a series of faint rings around it. This is called a diffraction pattern.

What causes those rings, and why does the star image turn into a disk? Why can't a skilled hand make the optics so well that the image is a tiny, precise replica of the star? The answer to these questions lies in the way light waves behave when passing through an aperture. It's similar to what happens to sound waves reproduced by a stereo system. No matter how good the amplifier is, it always distorts the audio signals passing through it. The perfect transmission of signals is prevented by the fundamental laws of physics, laws that cannot be broken.

The fidelity of the telescope's reproduction is limited by the aperture, or the distance across the front of the instrument. If the aperture increases, the angular size of the diffraction pattern gets smaller, and the light in the central spot gets squeezed into an even tighter pattern. This is why large-aperture telescopes can resolve finer detail and closer double stars than small telescopes.

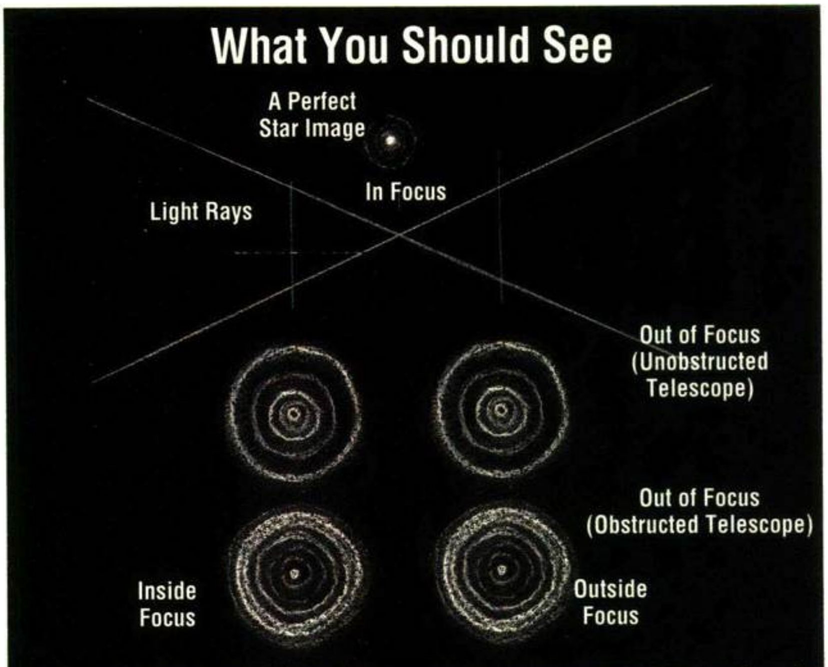
The central spot in the diffraction pattern is not a uniform disk, but it gets called one anyway. It is named the "Airy disk" after Sir George Airy. The "Airy Disk Sizes" table on page 58 shows you how the angular size of this central spot changes with telescope aperture.

Now let's do an experiment to demonstrate what the Airy pattern should look like in a perfect telescope. This will give us the standard by which to measure other telescopes. This demonstration will work provided your telescope is not completely defective and its optics are reasonably well collimated.

First, cut a smooth-edged 1"- or 2"-diameter circle out of a piece of cardboard and fix this mask to the front of your telescope. A 1" hole works best on telescopes with focal lengths less than 30 inches (750mm); use 2" holes on longer focal length telescopes. With refractors put the mask over the center of the lens. In a reflector offset the cut-out region just enough to avoid the secondary mirror and its supports.

Focus the telescope on a bright star like Vega or Capella that is high in the sky. Increase the magnification to between 50 and 100 power. What you should see is a diffraction pattern consisting of an Airy disk surrounded by a series of rings. The first diffraction ring is extremely subtle. Depending on the seeing conditions and the brightness of the image, you may see an even fainter second ring and possibly some rings farther out than that.

Slowly rack the star out of focus. As you do so you should see an expanding pattern of rings, with new rings created at the center as you rack the telescope farther out of focus. The effect is like ripples expanding on a quiet pond. Defocus the instrument to the point where four to six rings show. The important thing to notice is the way the light is spread more or less uniformly among the rings, except for a fat outer ring. (See the diagam at right.) That's the perfect diffraction pattern.



**In a perfect telescope all the light rays reach a common focus. When viewed at high power and precisely in focus, a star should appear as a tiny disk surrounded by faint rings (top). When viewed out of focus, the star image should appear as a series of concentric rings. Ideally the pattern will look the same on either side of focus. In an unobstructed telescope (such as a refractor), the out-of-focus pattern will be filled in (middle). In an obstructed telescope (a reflector with a secondary mirror), the out-of-focus pattern will look more like a donut (bottom).**

Now rack through focus to the same place on the other side. Notice how this is an identically lit disk, with a uniform distribution of light from the inside to the outside. Look at the crisp appearance of the edge. The edge does not appear to fuzz out or fade into the background on either side of focus. An out-of-focus star that looks the same on either side of focus is a sign of quality optics.

This ideal star image from our stopped-down telescope is shaped not by defects in the optics, but by the wave nature of light itself. Any telescope that claims to be "diffraction limited" must create a reasonable facsimile of that perfect pattern (albeit a smaller version) near its focus when used at full aperture.

### The Real Test

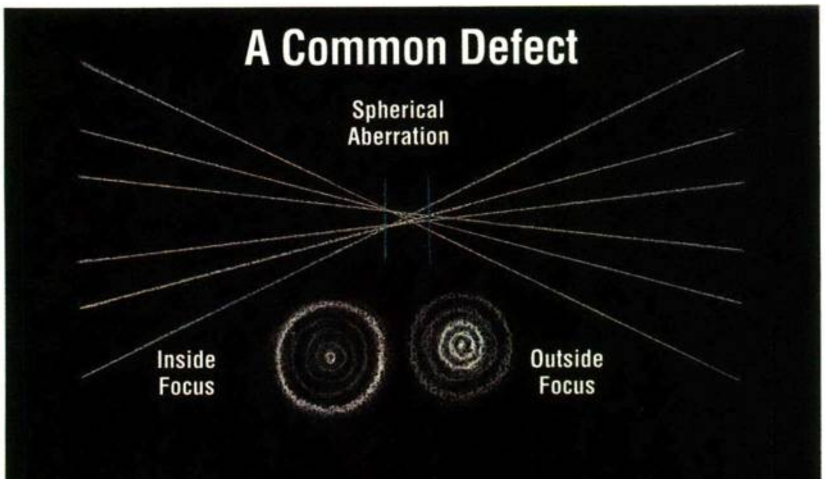
Now for the star test. It is quick, easy, and brutally sensitive. You merely remove the mask and test the whole aperture. The idea is to examine the appearance of the out-of-focus star disk (called the "extrafocal image," no matter which way it is defocused) both inside and outside of focus. Comparing the patterns on both sides of focus can reveal subtle errors in the optical surfaces.

At this stage it is no longer necessary to see the Airy disk clearly, so you don't need 50 power per inch of aperture: 20 to 25 power per inch is fine. For an 8-inch f/10 Schmidt-Cassegrain that works out to 160 to 200 power, or a 13mm to 10mm eyepiece.

Do the star test with the image centered in the field of view. Aim at a 2nd-magnitude star and defocus it so that four to eight rings are visible. If you defocus it too far the test loses its sensitivity. If you don't take it sufficiently far out of focus it is difficult to identify the source of the poor image. I've heard people complain that even though other tests have proven their telescope is bad, the star test still presents identical images on either side of focus. If so, the star test was performed too far out of focus.

If the ring pattern in your telescope does not look the same on either side of focus, chances are the optics are "undercorrected." Undercorrected optics produce images that have a problem called spherical aberration. The undercorrected surface brings light from the perimeter of the primary mirror to a closer focus than light imaged by the mirror's center area. There is no single focus point for all the light rays. (See below.) The result is an image that never achieves a sharp focus and always looks mushy. Inside of focus the light rays bunch up towards the rim of the disk; outside of focus they crowd in towards the center. Thus the star image looks different on either side of focus.

Undercorrection is the most common problem in commercial Newtonian reflectors. Their mirrors tend



**In many telescopes the mirrors are undercorrected. In these systems light rays from the perimeter of the mirror focus close in while light rays from near the center of the mirror focus farther out. This produces spherical aberration. The result is images that never snap into sharp focus.**

## Airy Disk Sizes

| Telescope Aperture (Inches/mm) | | Airy Disk Diameter (Arcseconds) |
|---|---|---|
| 1 | 25.4 | 5.4 |
| 2.4 | 60 | 2.3 |
| 3 | 76.2 | 1.8 |
| 3.2 | 80 | 1.7 |
| 4 | 102 | 1.4 |
| 4.3 | 108 | 1.3 |
| 5 | 127 | 1.1 |
| 6 | 152 | 0.9 |
| 8 | 203 | 0.7 |
| 10 | 254 | 0.5 |
| 12.5 | 318 | 0.4 |
| 17.5 | 445 | 0.3 |

to be insufficiently corrected. The mirrors are not parabolized properly. If a Newtonian tests poorly, odds are this is why.

You'll see quite a different set of extrafocal images in refractors. This is because all the colors don't come to a common focus. In standard two-lens achromats (most 60mm and 80mm beginner telescopes), orange-red and blue-green focus together slightly farther back than yellow, deep red focuses somewhat farther, and violet focuses quite a long distance back. Luckily, the eye is not very sensitive to deep red or violet light. If you've ever looked at a bright planet through a large refractor, you've probably noticed a violet haze surrounding the in-focus image. This is the unfocused violet light.

On a white test star such as Spica, the proper behavior is as follows: Inside of focus, with a disk of about three rings, you should see a greenish yellow disk with perhaps a red fringe. Passing through focus, just as the disk begins to expand again, you'll see a tiny red point form at the center of the pattern. The same greenish yellow disk is evident without a fringe. Even farther back a violet blur forms at the center but never really focuses.

## Secondary Obstruction

| Percentage of Diameter Blocked | Percentage of Light Focused into Airy Disk |
|---|---|
| 0 (Unobstructed) | 84 |
| 10 | 82 |
| 15 | 80 |
| 20 | 77 |
| 25 (Newtonians) | 73 |
| 30 | 68 |
| 35 (SCTs) | 64 |
| 40 | 58 |
| 50 | 49 |
| 75 | 22 |

This description has become dated, however. New refractors containing fluorite lenses or three lenses are now commercially marketed. They have altered color behavior from the classic crown-flint doublet, either compressing the residual color error or forcing three colors to focus together. Don't look for the regular behavior I've just described for ordinary refractors in these telescopes. Look for obvious signs of error, such as a strong color flare around focused images, particularly in colors where the response of the eye is strong. Some of these apochromatic refractors have as part of their design a distant violet focus nearly as noticeable as an ordinary refractor's. A violet halo is no indication of a defect in these apochromats, but a purple or green halo is.

Watch out for another type of color error. If the error is not symmetric around the image but seems to be drawn out in a little rainbow streak, you may have a problem with decentered or wedged lens elements. Make certain that the rainbow isn't an atmospheric effect, however. If you are looking at a star that is below about 45° altitude, the atmosphere itself may be acting as a prism.

With a fast f/ratio refractor you may want to use a yellow filter when testing for anything *except* color error. In fact, this is a good idea even when testing reflectors — it removes possible interfering color error originating in the eyepiece.

### Don't Blame the Telescope

In the real world all kinds of other factors besides the quality of the optics can ruin star images. To test your telescope fairly, you need to reduce these outside effects. Otherwise you may be blaming your telescope for a defect it doesn't have.

*Atmospheric Turbulence.* The first of these interfering factors is the atmosphere. On nights of poor seeing turbulent air cells sweeping over the image can turn it into a boiling confusion. When this happens, don't bother testing. Because big telescopes look through a large volume of air, problems of this sort disturb large scopes more than small ones, making it more difficult to find a good night to test large scopes.

*Tube Currents.* Slow-moving currents of warm air inside your telescope can introduce defects that mimic permanent errors on the glass. Depending on where the currents lie and which side of focus you're on, the star image may have a stretched out region or a flat section on one side. Sealed tube instruments have similar errors, but they aren't caused by currents. They are more like puddles of cold air in warmer air. These cause prismatic errors or variations of the tube current patterns.

A way of checking for tube currents or puddles is to fan the inside of the tube (an assistant helps) or invert the telescope. That will usually break the pattern long enough to identify it. Tube currents occur when you take a telescope from a warm house into the cold night air. When star testing, always give the telescope a chance to come to temperature. Go back in and enjoy some hot chocolate while it does.

*The Eyepiece.* To do a star test you should use a good quality eyepiece. On ultra-fast reflectors, no eyepiece works at its best, but a high quality Plössl or orthoscopic is the least you should use. If the telescope fails (more importantly, if everyone else's telescope fails in the same manner when using the same eyepiece), suspect the eyepiece. Don't use a Barlow lens, as that may add some optical errors of its own. Likewise, do not use a star diagonal. Always look straight through the telescope.

*The Eye.* If you have simple nearsightedness or farsightedness, you probably take off your glasses when observing. But if your glasses have strongly curved lenses or correct for astigmatism, leave them on. You don't want to confuse astigmatism in your eye with astigmatism in the telescope.

*Telescope Collimation.* A telescope that is out of collimation is unfairly judged by the star test. For example, an out-of-focus star in a misaligned Newtonian reflector looks like a striped, tilted cone as viewed from the pointy end. This is a mixture of two forms of error, coma and astigmatism. Images suffering from coma look like comets; the light is smeared sideways. Astigmatism refers to a stretching of the image along an axis. The net effect of combining the two gives an egglike appearance.

Poor collimation is the most easily fixed error in Newtonian reflectors and Schmidt-Cassegrains. Both types of telescopes have adjustment screws on the primary or secondary mirrors for just this purpose. If there are no adjustment screws (often the case on small refractors), return the telescope if it seems poorly aligned.

Contrary to popular belief, collimation is easy. All you have to do is grit your teeth and do it once. It is a lot like riding a bike — the first time is the hardest. Go ahead and try this test right now. Put your eye in the center of the focuser tube (without eyepiece). If your scope is a reflector, do all of the circles you see have the same center? For refractors, leave the lens cap on and look up the tube. Are all the multiple reflections centered? If not, the telescope needs collimation.

On Newtonian telescopes you make coarse adjustments on the secondary mirror first, then final small adjustments to the main mirror. On all but the smallest Newtonians this is best handled by two people, one at the eyepiece end giving instructions and the other at the mirror end swearing that he only barely touched it. For a Schmidt-Cassegrain the only adjustments are the three screws on the secondary mirror. (Check your instruction manual for details.)

In either case, the trick is to use the collimation screws to move the out-of-focus star image in the same direction that it is stretched out. You can find out which screw to turn by sticking your hand in front of the telescope and darkening part of the image. Move your hand around until it is lined up with the deformation. Adjust the screw that lines up most nearly with the place your hand is covering (or, the two opposite screws equally). Recenter the image and look at it again: It's either better or worse. If it's worse, undo the damage and turn the screw the other way. If it's better, decide whether you have to go farther or turn yet another screw.

With a little trial and error you'll soon have a neatly centered image. With experience it may take you only five minutes to align your telescope. The first time may take you half an hour, after which you'll be sweating profusely. But the improved images will make you glad you learned. However, if you are unable to achieve good collimation, it may be due to another problem such as...

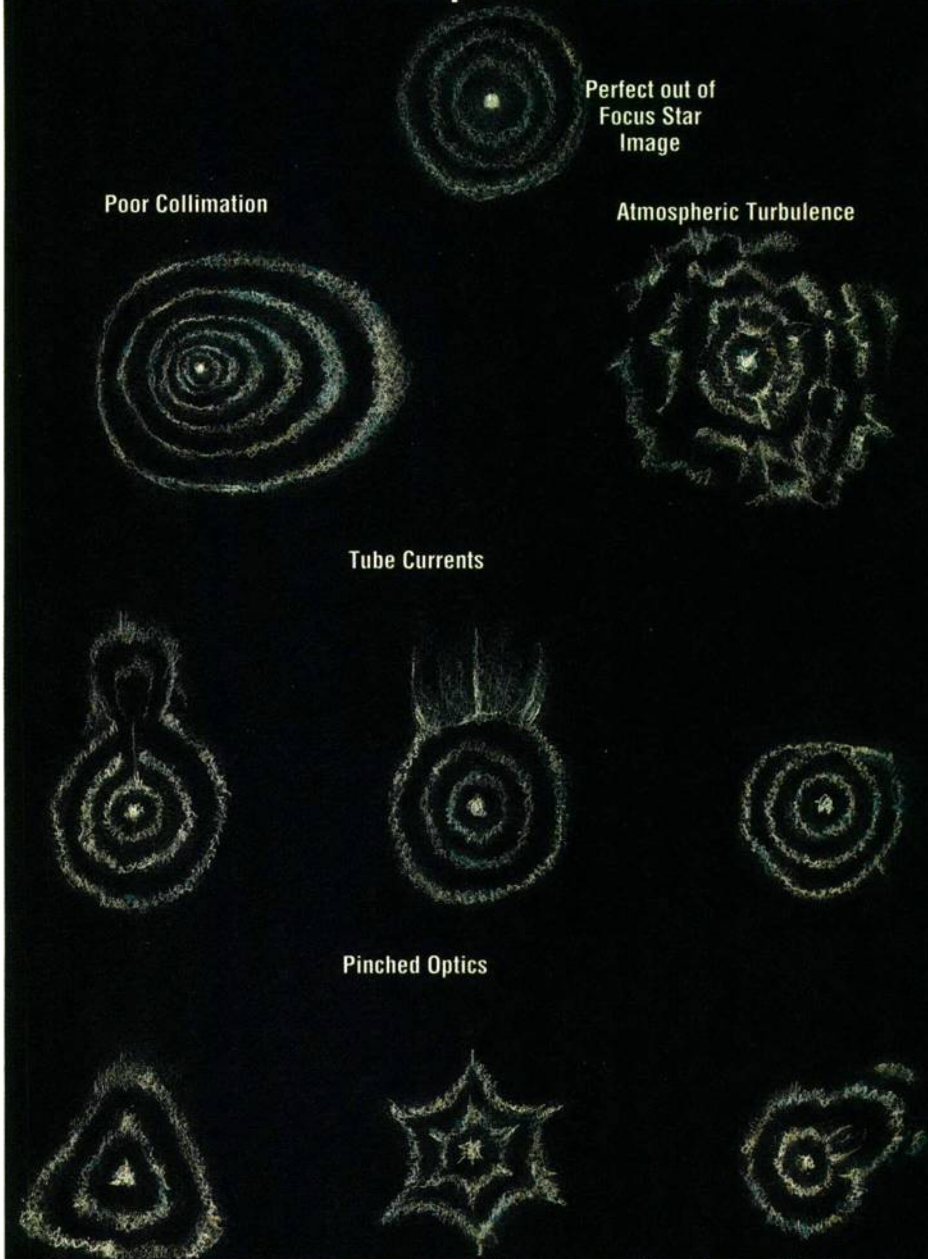
*Pinched Optics.* Badly mounted optics can create some very unusual diffraction patterns. Most common for Newtonians is the triangular or hexagonal spiking or flattening (depending on which side of focus you are on). This is caused by screwing the mirror clips down too tightly on 3- or 9-point mirror cells. The mirror buckles slightly under such pressure. Secondary mirrors glued onto holders can also suffer from pinching.

Other deformations can result in even more obscure patterns. I once saw an out-of-focus image produced by a new Schmidt-Cassegrain that had a severely pinched corrector plate. The pattern was not symmetrical. It had a warped secondary loop in the pattern (like an atmospheric turbulence cell, only not moving). Since the thought of removing a Schmidt-Cassegrain corrector plate made me weak in the knees, I told my friend what was wrong with it but didn't help him fix it. Somebody else helped him remove it and remount it. He later chided me about that.

### Defects on the Glass

Now we get to the heart of the test: determining if there is a defect in the optics themselves. Errors on the optical surface are divided into

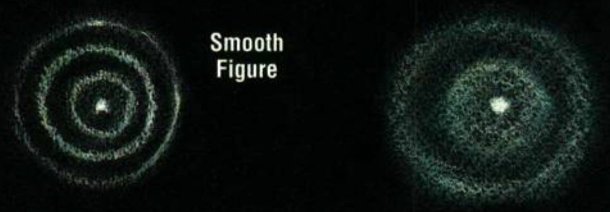
## Don't Blame the Optics If You See These



Strange out-of-focus star images may not be due to poor optics. Poor collimation may produce elliptical images. Tube currents cause a distortion on one side of the image. Atmospheric turbulence causes an overall distortion that slowly moves around. The non-circular patterns produced by pinched optics are caused by the way the optics are mounted, not the optics themselves.

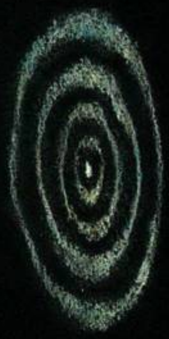
## The Optics Have a Defect If You See These

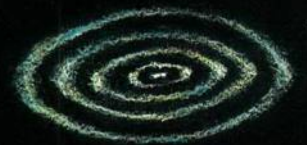
### Roughness



Bumpiness in the surface figure will cause the rings to fuzz out.

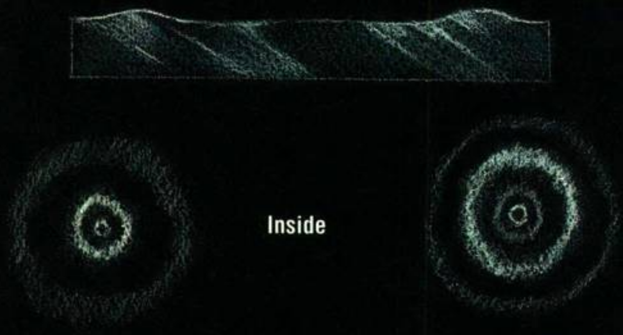
### Astigmatism




The Other Side of Focus

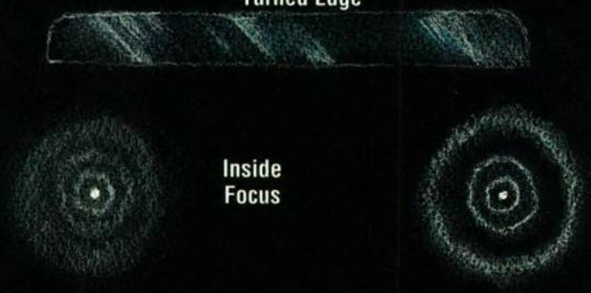
If the out-of-focus star looks elongated and flips over 90° from one side of focus to the other, the optics may be astigmatic. This can also be caused by pinched optics.

### Zonal Error



A "zone" is a ring-shaped region around the mirror or lens that is higher or lower than the ideal surface shape.

### Turned Edge



A turned-down edge is a form of zone. The edge of the mirror or lens is lower than the ideal surface.

categories. But the diffraction image doesn't care what causes the error and often doesn't neatly follow the textbook patterns we've depicted in the illustrations. Errors combine to mix up the patterns. However, one error usually dominates, making the diagnosis fairly obvious.

*Undercorrection and Overcorrection.* We've already seen the results of undercorrection. The opposite pattern, a fuzzball inside of focus and a doughnut outside of focus, is due to overcorrection. That's what you would get with a Newtonian that has a hyperbolic mirror instead of a parabolic mirror. Both under- and overcorrection cause spherical aberration, which in turn leads to fuzzy images.

But be careful. Don't confuse the secondary mirror's shadow in the ring system with a problem in the correction of your instrument. At some point in defocusing the center of the expanding cone of light is no longer illuminated in obstructed telescopes. The key here is to make sure it looks identical on both sides of focus. You can also use this as a test for mild correction error. Go to the position of best focus and note how far you have to turn the focuser knob to see the secondary shadow break out in the middle. Turn the focuser the other way and see if the breakout point is an equal distance on the other side of best focus. This technique reveals small spherical aberration errors that may otherwise be hard to find but may not impair performance significantly.

*Zones.* Zones are shallow valleys or low hills that are arranged in rings on the optical surface. Many machine-made optics suffer from zones to some extent. Severe cases degrade image quality noticeably. To check for zones defocus the image more than is usual in the star test. On one side of focus or the other you may notice that one or more rings looks weak.

*Turned Down Edge.* A special case of a zone is the turned-down edge. This is a rounding-off of the edge of the mirror or lens caused by unusual polishing pressure. It is a defect equally common in amateur-made and commercial optics. Turned edges can be troublesome because the perimeter of a mirror or lens represents a large fraction of the light-collecting area.

In reflectors a turned-down edge displays its presence in the star test by a "fuzzing out" of just the edge of the disk *inside* focus. As you approach focus the diffraction pattern looks flat and the rings don't look crisp. Outside of focus the diffraction pattern is less disturbed and is difficult to distinguish from one produced by a perfect mirror. For refractors the reverse is true: The disk has a fuzzy edge *outside* of focus. However, refractors cover the edge in mounting cells, so a turned-down edge appears much less often in a refractor.

I have never seen turned-edge in its pure form unmixed with other aberrations, so the illustration at left represents something of a guess.

*Astigmatism.* If an optical surface is ground or polished on an uneven backing or with an uneven stroke, or if improperly annealed glass is used, a permanent cylindrical shape can be the result. Astigmatism causes a star image to turn into a stubby line or an ellipse that flips over at right angles as you rack from one side of focus to the other. The best focus looks vaguely crosslike. The easiest way to detect astigmatism is to rock your focuser back and forth quickly. Mild astigmatism is best seen with the star only slightly defocused.

The problem with astigmatism is isolating it to an error on the glass. It can sometimes arise from a misaligned telescope. Some people also have astigmatism in their eyes and don't know it. Rotate your head and see if the distortion follows. Turn the eyepiece to check it. If the pattern turns too, the eyepiece is at fault.

In addition, astigmatism can be a symptom of poorly mounted optics. If you find astigmatic images in a Newtonian, loosen the mirror clips of your primary and mount the diagonal less tightly. In refractors or complicated commercial designs with no user adjustments, the optics mounting is part of what you are testing. In these telescopes a case of astigmatism is cause for returning the instrument for an exchange, refund, or repair.

Astigmatism in Newtonians may also indicate a diagonal that is not flat. To test this rotate the main mirror 45°. See if the pattern rotates by the same amount. If it does not, the diagonal is bad or you have a problem with poorly mounted optics.

*Rough Surfaces.* Another common problem with commercial optics is a kind of bumpiness or relief pattern caused by harsh machine polishing. Its nickname is "dog biscuit." It appears in the star test as a lessening of contrast between the rings plus the appearance of spiky appendages to the rings. Don't confuse spider diffraction with these spikes; spider diffraction is spaced regularly. If you see a velvety smooth ring system, you don't have trouble with roughness. Since other aberrations can often obscure the appearance of rings on one side of focus or the other, you must inspect the image to see if the rings appear on both sides of focus.

Reflectors have problems with roughness more often than refractors. In fact, a good way to see what a smooth surface looks like is to put a yellow filter in a high quality refractor. The way to tell if this error originates on the glass, or is "preroughened" by the atmosphere, is to watch it for a while. Atmospheric errors move, errors on the glass are disturbingly still.

### What If Your Telescope Fails?

Nearly all telescopes have questionable results on one or more of the star test evaluations. This is not because they are poor instruments, but because the star test can be astonishingly sensitive. It is much more effective than other techniques like the Foucault test, the Ronchi test, or splitting double stars. So before flunking any telescope do some other checks.

How does the telescope perform on the "snap" test? One of the quickest star tests you can perform is to watch the image as it passes through focus. Does the focus seem to snap into place, or does it ooze uncertainly through focus? If it snaps, it is doing well. If it performs poorly on this easiest of star test techniques and you've just bought the telescope, talk to your dealer about exchanging the instrument.

How does it do in comparison with other instruments of similar size and focal length? If your telescope always performs poorly in comparison with others, maybe you've found out why.

Fatal errors on any instrument include turned edge, any astigmatism that originates on the glass, easily seen over- or undercorrection difficulties, bad zones, severe roughness, or any unusual color error. Non-fatal errors include small correction errors that are not strikingly obvious, mild zones (particularly zones near the center), and light roughness. With minor errors like these you must weigh the likelihood that a replacement telescope may not be any better and may in fact be worse.

You must also consider what you want the telescope to do. If you bought the telescope as a low-cost light bucket, maybe you shouldn't judge it too harshly. On the other hand if you paid a premium price for a telescope advertised as "diffraction limited," you have a right to demand high quality.

With the star test you have a newfound power to find fault in telescopes. With that power comes responsibility. Because the star test is so quick and easy, it's tempting to perform it on every telescope you see. The problem is that you may collide with the emotional investment people have in their equipment. They often don't want to hear what is wrong with their telescopes. It may not be a good way to impress your friends.

If the worst happens and *your* telescope fails the star test, don't immediately get angry with your dealer or manufacturer. For one thing, you may be wrong. Even this easy test requires some experience to perform correctly. Try it on other instruments. Get a second opinion. Ask more knowledgeable members of your local amateur group to star test your telescope. If the telescope still fails, don't fly off the handle. Work with the dealer or manufacturer responsibly and you will probably receive satisfaction.

Finally, ask yourself, "How good does my telescope really have to be?" Naturally we want the equipment we own to work as well as possible, but I have seen observers spend many satisfying hours with telescopes that barely worked. Others hardly used instruments that approached perfection. They were always whining about how rotten their images looked.

In the end, as many amateurs have discovered, the telescope that gives you the most enjoyment may not be the one with the finest optics but the one that you use most often. □

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*Dick Suiter is an amateur astronomer and telescope maker from Panama City, Florida, who enjoys deep-sky observing.*

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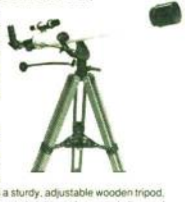

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9mm #8582, 12.5mm #8583

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18mm #8584, 25mm #8585
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25mm #8564 **$79** (2.19)

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**Schmidt-Cassegrain UltraBlock Filter**- fits rear cell of Meade & Celestron SC scopes. #5656 **$119** (2.19)

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.965" #5558 **$19.95** (1.89) 1.25" #5560 **$24.95** (1.89)

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*Deluxe Model*-
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**2x .965" Barlow Lens** #8742 **$27.95** (1.89)

## Orion® Dew Zapper

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*8" Dew Zappers*- fit all Meade & Celestron 8" Schmidt-Cassegrains

DC Model #3503 **$34.95** (1.79)

AC Model #3504 **$34.95** (1.79)

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DC Model #3506 **$39.95** (1.79)

AC Model #3508 **$39.95** (1.79)

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#5601 **$17.95** (2.09)

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#5709 **$8.95** (1.89)

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#5714 **$24.95** (1.89)

## Astronomer's Flashlight

Indispensable and indestructible. Has special night-vision red filter and a diffusion lens for even illumination. An essential addition to your astronomy accessories. Requires 2 D-cell batteries (not included).

#5701 **$8.95** (1.89)

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Perfect for Meade LX6, LX5, and LX3; and Celestron Powerstar 8, and SPC-8 (with adapter). Also suitable for all drive correctors and motor drives. Battery is encased in high-impact polystyrene. Built-in handle. Wt. 5 lbs.

#2352 **$69 ea.** (4.56)

*12 Amp Hour Porta Pac*
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#2354 **$99 ea.** (6.23)

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#8748 **$69.95** (2.19)

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#8746 **$49.95** (2.09)

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Unlike ordinary counter-weights, our system allows instant adjustment in both directions. Easily balances your scope to offset both piggyback loads or rear-cell cameras, 2" diagonals, and other accessories. Rigid, precision machined dovetail bar mounts to telescope in existing accessory holes.

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**For Celestron 8" C-8** #5149 **$79.95** (3.46)

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Use with any 1.25" Illuminated Reticle Eyepiece. For Meade and Celestron Schmidt-Cassegrains.

#5144 **$59.95** (1.89)

## Universal Camera Adapters

*Standard Universal Camera Adapters*
Combination Eyepiece Projection Tube and Prime Focus Adapter for refractors and reflectors with 1.25" eyepiece holders. Use with T-Ring (sold separately) to match your 35mm camera.

.965" #5268 **$29.95** (1.89)

1.25" #5264 **$34.95** (1.89)

*Variable Power Camera Adapter*
Unique sliding barrel design allows variable projection distances during eyepiece projection photography, eliminating the need to change eyepieces when magnification changes are required.

#5262 **$44.95** (1.89)

## Orion® T-Adapter

For prime focus photography. Use with T-ring to match your 35mm camera. For Meade, Celestron 8", 10" SC.

#5116 **$27.95** (1.89)

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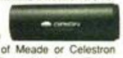

*Standard Tele-Extender*
Use this Tele-Extender in conjunction with an eyepiece. Attaches to visual back of Meade or Celestron Schmidt-Cassegrain telescopes, and to 35mm camera with T-ring, sold separately.

#5125 **$27.95** (1.89)

*Variable Tele-Extender*
Uses an adjustable extension tube, allowing magnification to be changed without switching eyepieces. Thumbscrews lock extension tube securely in place. Attaches to 35mm camera with T-ring, sold separately.

#5127 **$39.95** (1.89)

## Orion® Tele Compressor

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#5128 **$89** (2.29)

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Same as 1.25" Star Diagonal, but with standard coated optics. Works with .965" eyepieces and eyepiece holders.

#8761 **$24.95** (1.89)

## Hybrid Star Diagonal

Adapts 1.25" eyepieces to .965" eyepiece holders of refractors and most compound reflectors.

#14008 **$29.95** (1.89)

## 2" Star Diagonal

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#8767 **$89.95** (2.59)

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# Great Summer Planetaries

The summer Milky Way is resplendent with bright planetary nebulae like the Ring, the Dumbbell, and the Blinking Planetary.

by Alan Goldstein

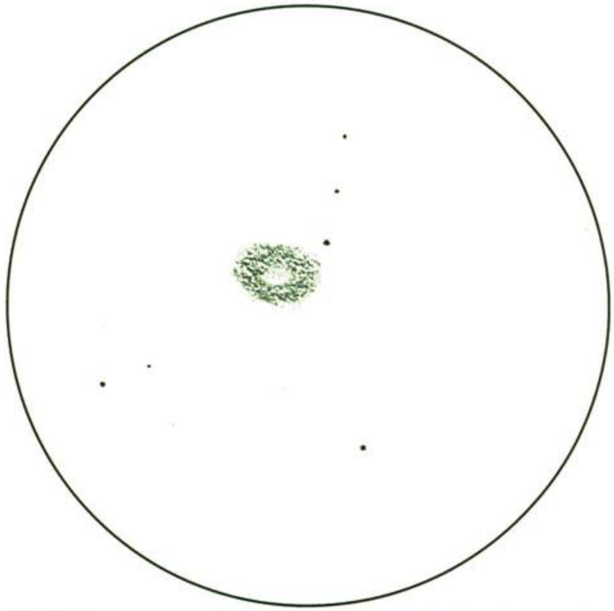
Planetary nebulae have a lot to offer to backyard observers. These cosmic puffballs cover the entire spectrum of observational difficulty: Some are easily spotted with large binoculars, while others demand special filters and a big dose of patience to distinguish from the background stars. But regardless of whether you just want to marvel at the beauty of bright planetaries or you want the challenge of finding the faint ones, the best planetary nebulae can be found in the summer sky.

The finest planetary nebula in the sky is the **Ring Nebula** in Lyra (M57 or NGC 6720). The Ring is one of the most distinctively shaped of all deep-sky objects, although its appearance is something of an optical illusion. Not actually ring-shaped, it is a sphere of gas puffed away by its central star. It only looks like a ring because most of its light comes from the thick edges of the shell.

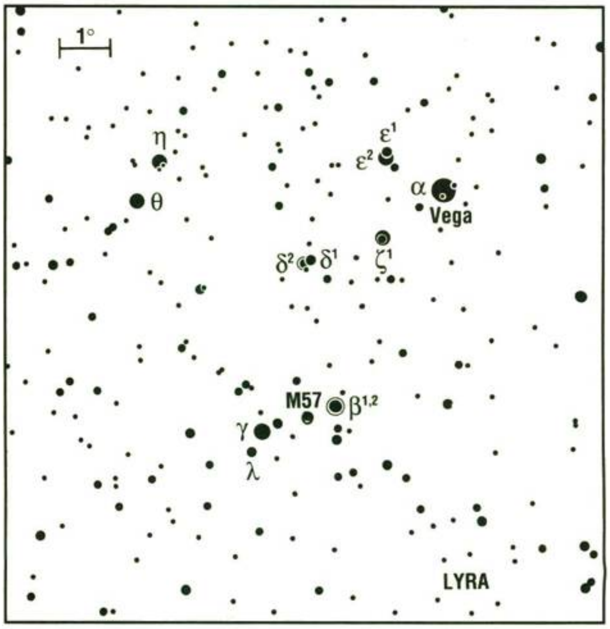
Although the Ring is bright, its small size (just over 1' in diameter) makes it difficult to distinguish from field stars when viewed with a 6x to 10x finder scope. In large binoculars or a 2-inch telescope at 20x to 50x, the Ring looks like a pale gray disk. A 3-inch telescope at 150x will show the Ring's distinctive shape, but only when you use averted vision. However, a 6-inch telescope's greater light grasp unmistakably shows the ring shape at 100x. In 8-inch and larger telescopes the Ring appears like an oval gray-green disk with a dark central hole. Still larger scopes reveal a dimly glowing haze within the central hole.

The most difficult observing challenge associated with the Ring Nebula is spotting its faint central star. Cataloged at magnitude 15.7, this white dwarf star is extremely elusive. Based solely on its magnitude, the central star should be visible in a 16-inch scope on a dark, transparent night. Some particularly keen-eyed observers with 5-inch telescopes have spotted the star. However, astronomers with 40-inch telescopes at professional observatories have sometimes missed seeing this star.

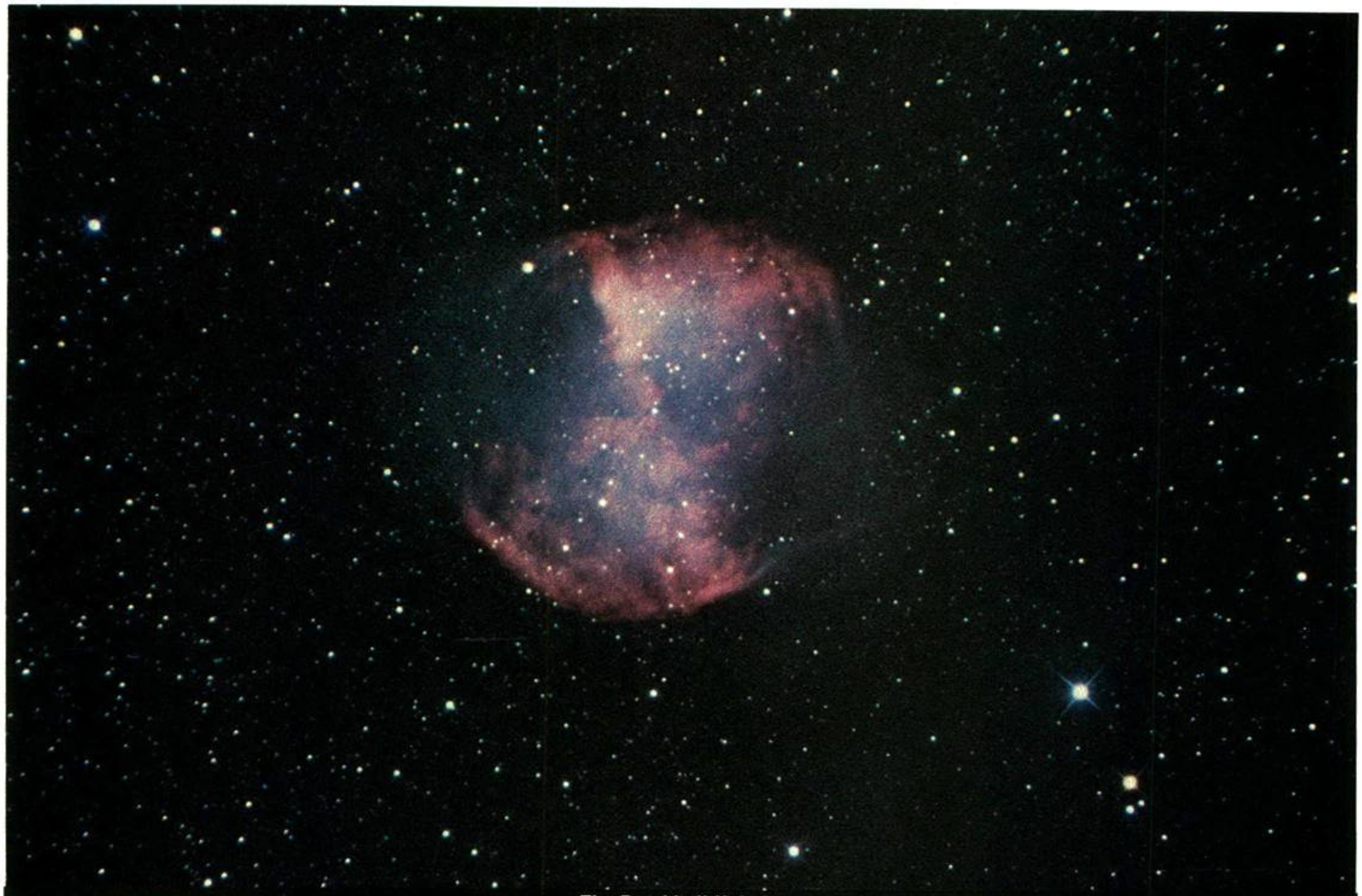
To explain this puzzle, astronomers have hypothesized that the Ring's central star varies in brightness. Also, its strong blue tint probably means that observers with eyes sensitive to blue light have a much easier time seeing the star than do observers whose eyes are more sensitive to red light. Nonetheless, the mystery of the Ring's central star will surely continue as one of the strangest stories in deep-sky observing.



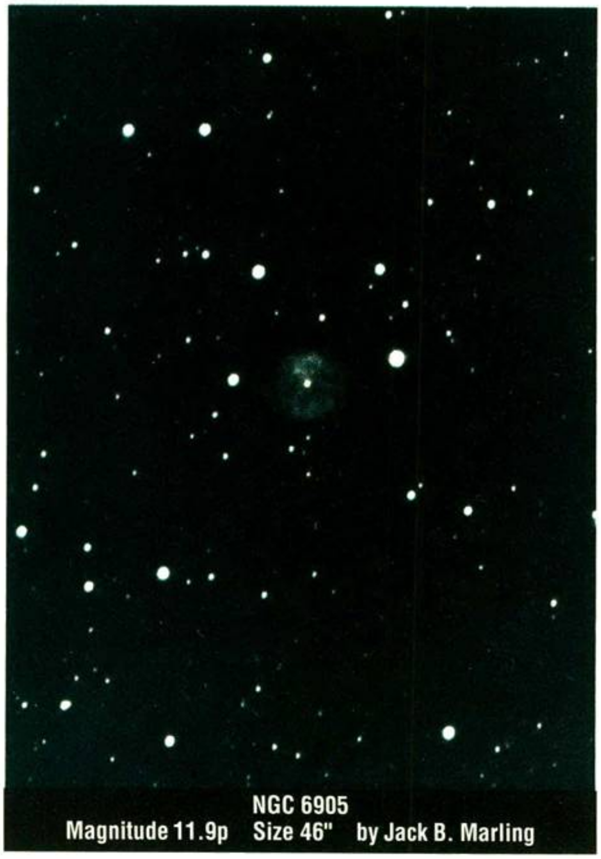
**The Ring Nebula**
**8-inch f/10 SCT at 50x by David J. Eicher**



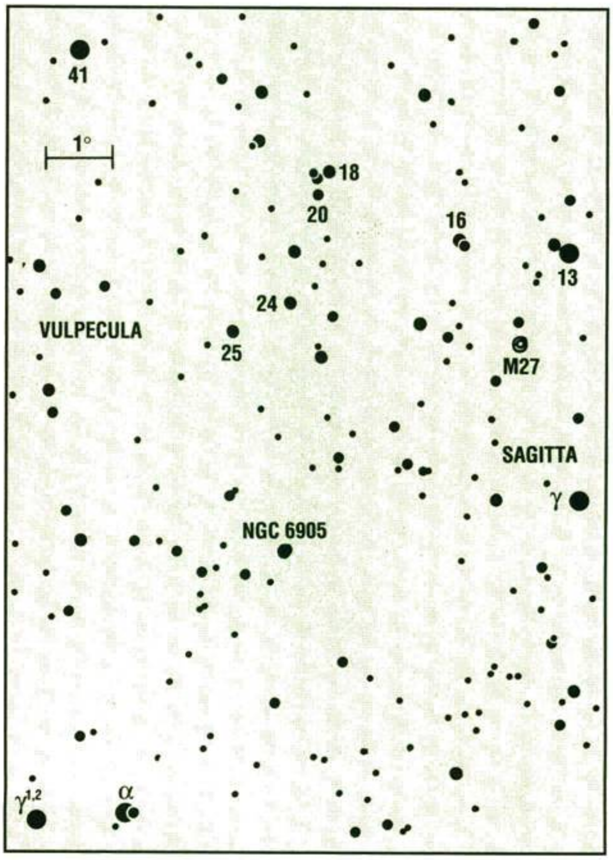
The Ring Nebula
Magnitude 9.7p Size 70" by John Gleason

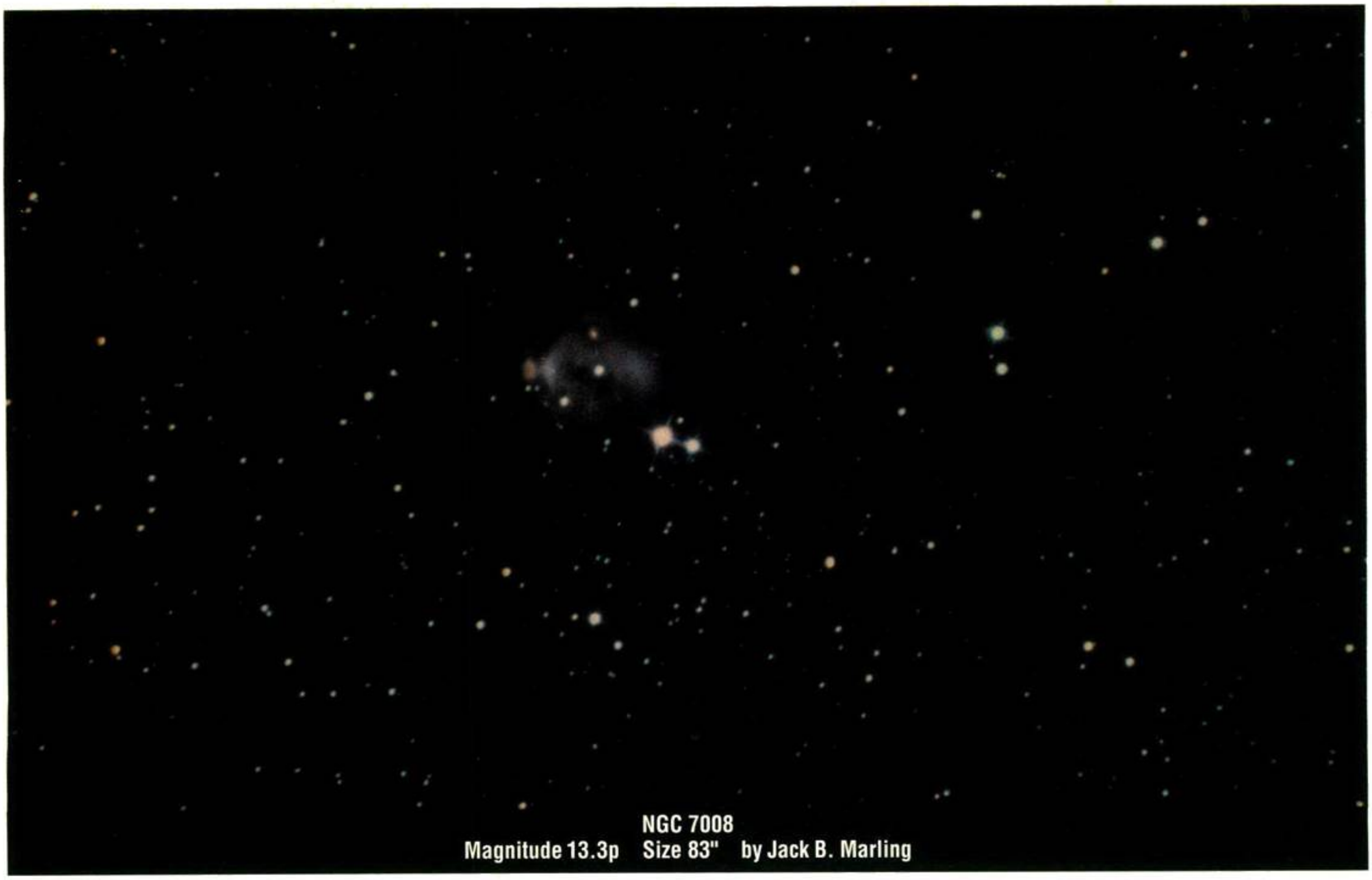


The Dumbbell Nebula
Magnitude 7.6p Size 350" by Jack B. Marling

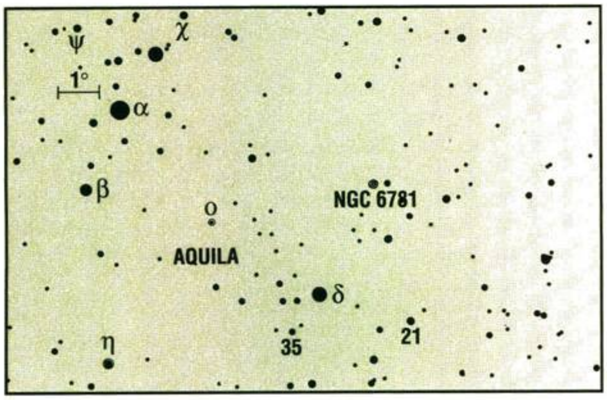


NGC 6905
Magnitude 11.9p Size 46" by Jack B. Marling


41
1°
18
20
16
13
24
VULPECULA
25
M27
SAGITTA
γ
NGC 6905
γ1,2
α



NGC 7008
Magnitude 13.3p Size 83" by Jack B. Marling



Second only to the Ring in visual appeal is the **Dumbbell Nebula** in Vulpecula (M27 or NGC 6853). The Dumbbell can be found by scanning 2° due north of Gamma Sagittae to a C-shaped group of stars about 30' south of 14 Vulpeculae. The Dumbbell Nebula lies in the center of this distinctive star group.

Named for its unique shape, the Dumbbell is visible through a 3-inch telescope at 150x as a disk with two giant bites out of it. (Some observers think it resembles a butterfly more than a dumbbell.) Like the Ring Nebula, the Dumbbell has a high surface brightness and holds up well under high magnification. If the night is steady and dark, don't be afraid to use 200x or more to see detail in the Dumbbell.

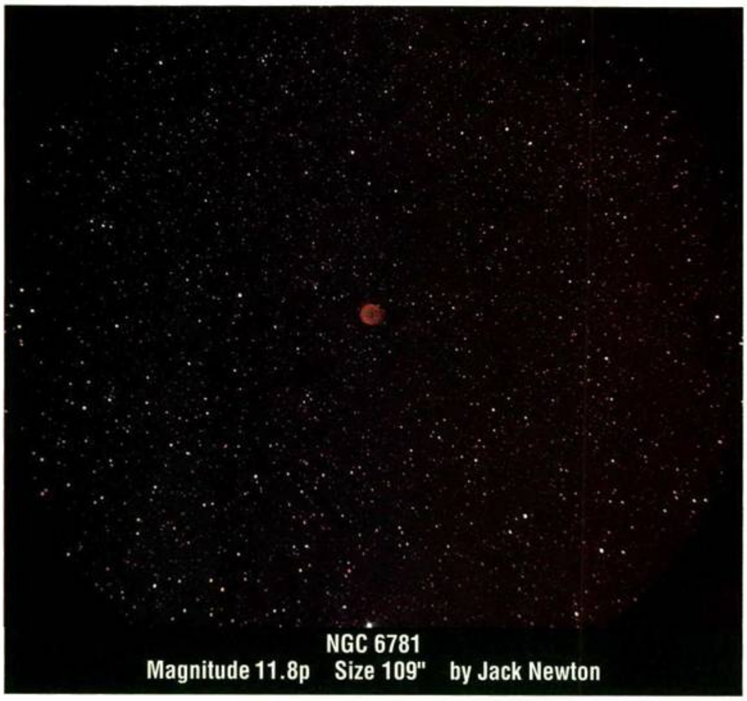
On first viewing this object you'll see that it is not uniformly illuminated across its disk, which gives it a patchy appearance. Several foreground stars are visible superimposed on the face. The Dumbbell's central star glows at magnitude 13.5, making it visible with an 8-inch scope.

Northward into Cygnus, **NGC 6826** can be found less than 5' east of the 6th-magnitude star 16 Cygni. With a magnitude of 9.8 and a central star shining at magnitude 9.9, NGC 6826 is difficult to miss in a small telescope. It is rather small, measuring 30" across, so be sure to use at least 100x when you zero in on the nebula's position. When you come across the right field you'll see that NGC 6826 has a bright, nonstellar blue-green disk. You may see the central star immediately when you scan across the nebula.

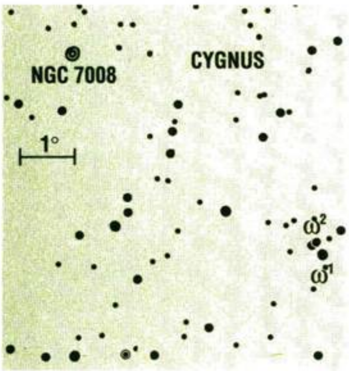
The visual relationship between nebula and central star is most unusual in the case of NGC 6826. When you look directly at NGC 6826, the nebula disappears and you see only the central star. When you look slightly to one side of the field, however, the star disappears and the nebula pops into view. This peculiar effect gives NGC 6826 its nickname, the Blinking Planetary.

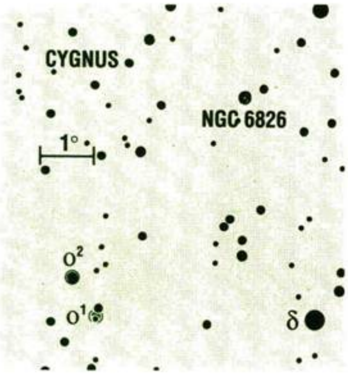
Another wonderful Cygnus planetary is **NGC 7008**, a large, ghostly shell of light. Located in the northernmost reaches of this constellation close to the Cepheus border, NGC 7008 lies midway between Mu Cephei and Omega$^2$ Cygni. Its diameter of 83" makes it one of the largest planetary nebulae in the summer sky.

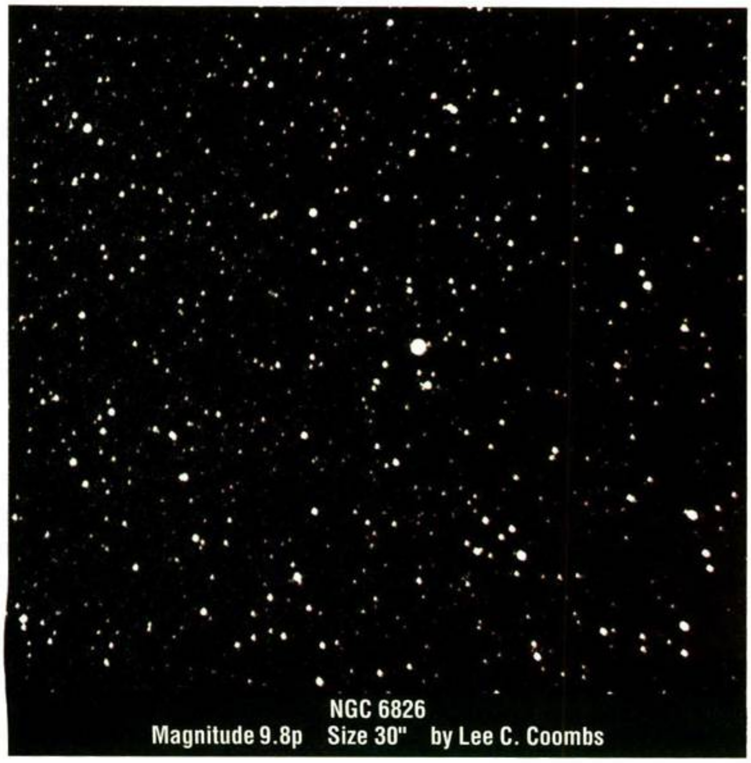
Most sources assign NGC 7008 a magnitude of 13, so in a small telescope this object appears large and diffuse with a low surface brightness. The best views of this object come with a 10-inch or larger scope at 100x. The nebula's central star, a 12th-magnitude dot, is within the reach of 6-inch telescopes under dark skies. NGC 7008 has an irregular



NGC 6781
Magnitude 11.8p Size 109" by Jack Newton







NGC 6826
Magnitude 9.8p Size 30" by Lee C. Coombs

## Great Summer Planetaries

| Object | R.A. (2000.0) | Dec. | Mag. | Size |
|---|---|---|---|---|
| M57 | 18h53.6m | +33°02' | 9.7p | 70" |
| NGC 6781 | 19h18.4m | +06°33' | 11.8p | 109" |
| NGC 6826 | 19h44.9m | +50°31' | 9.8p | 30" |
| M27 | 19h59.6m | +22°43' | 7.6p | 350" |
| NGC 6905 | 20h22.4m | +21°06' | 11.9p | 46" |
| NGC 7008 | 21h00.6m | +54°33' | 13.3p | 83" |

**Object:** Designation in Messier or NGC catalog. **R.A. and Dec.:** Right ascension and declination in equinox 2000.0. **Mag.:** Photographic magnitude. **Size:** Diameter in arcseconds.

but basically oval shape that is visible in telescopes as small as 8 inches in aperture.

**NGC 6905** is a bright planetary nebula in the small constellation Delphinus. Lying 2° southwest of the 6th-magnitude star 18 Sagittae, this nebula is large enough (46") and bright enough (12th magnitude) to be picked up in a 3-inch telescope with little trouble. Its oval shape becomes apparent in 6-inch scopes at 100x. This object bears magnification well, so use a relatively high-power eyepiece for the best view.

NGC 6905's central star glows dimly at about 14th magnitude and is invisible in telescopes smaller than 10 inches in aperture. I've always seen NGC 6905 as gray in color, although some observers have recorded a greenish or even bluish hue, especially when using telescopes larger than 16 inches in aperture.

**NGC 6781** is the most spectacular planetary nebula in Aquila. You can locate NGC 6781 by moving 2° north-northeast of the 5th-magnitude star 22 Aquilae. At magnitude 11.8, this large, ring-shaped object can be glimpsed in a 4-inch telescope. NGC 6781 measures 109" across, which gives it a relatively low surface brightness and makes finding it on less than dark nights somewhat challenging.

In small telescopes NGC 6781 appears as a pale, ghostly disk. Its ring shape becomes more pronounced as you view it through larger telescopes. Some observers have seen a ringlike shape with 8-inch telescopes. In larger apertures, the ring-shape is easy.

Like M57, Aquila's ring nebula is not symmetrical. The central "hole" is offset from the center of the circular disk, giving NGC 6781 the appearance of a ring that is thicker on one side than the other. The central star dimly glows at magnitude 15.4 and is visible only with the largest amateur telescopes.

Bright and faint, large and small, planetary nebulae offer a rich variety of shapes and details to challenge your observing skills. Why not unlimber your telescope and head out under the stars this summer when the best and the most challenging nebulae lie waiting overhead every night? ☐

---

*Alan Goldstein is the founder and director of the National Deep Sky Observers Society. He is also a contributing editor of* Deep Sky *magazine and a contributor to the book* Deep Sky Observing with Small Telescopes *(Enslow, 1989).*

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*Photo by Wolfgang Lille with a 6″ f/4.5 Newtonian and Celestron Coma Corrector. The Ring Nebula (M57) was 18mm from the center of the original photo. Note the superb edge definition.*

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Large, fast parabolic mirrors are desirable for deep sky photography and observation because they offer low power wide field views. However, the main problem with fast parabolic mirrors is that they introduce coma (and to a lesser degree, astigmatism). Coma is distortion of star images near the edge of the field that reduces the size of the usable field of view. To eliminate coma, several companies have introduced coma correctors, lenses that are placed near the focus point and reduce the severity of the coma. The problem is that most of these increase the telescope's f/ratio and focal length.

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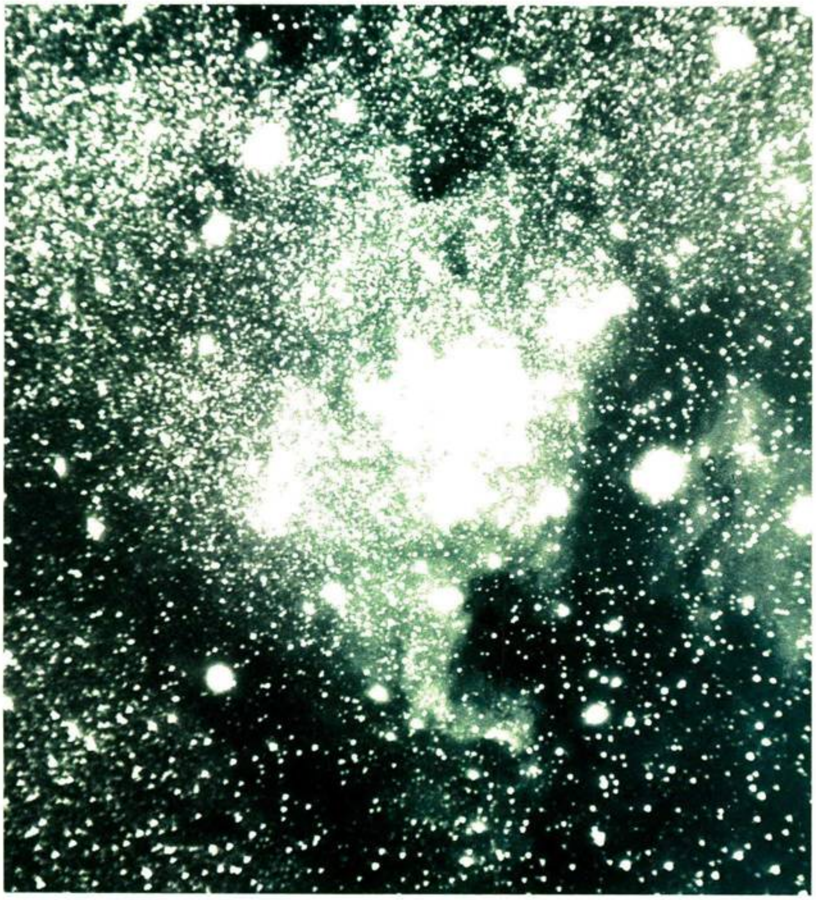
# A Summer Piggyback Portfolio

Look at the results you can get with a camera and lens piggybacked on your telescope.

by Matthew F. Willson

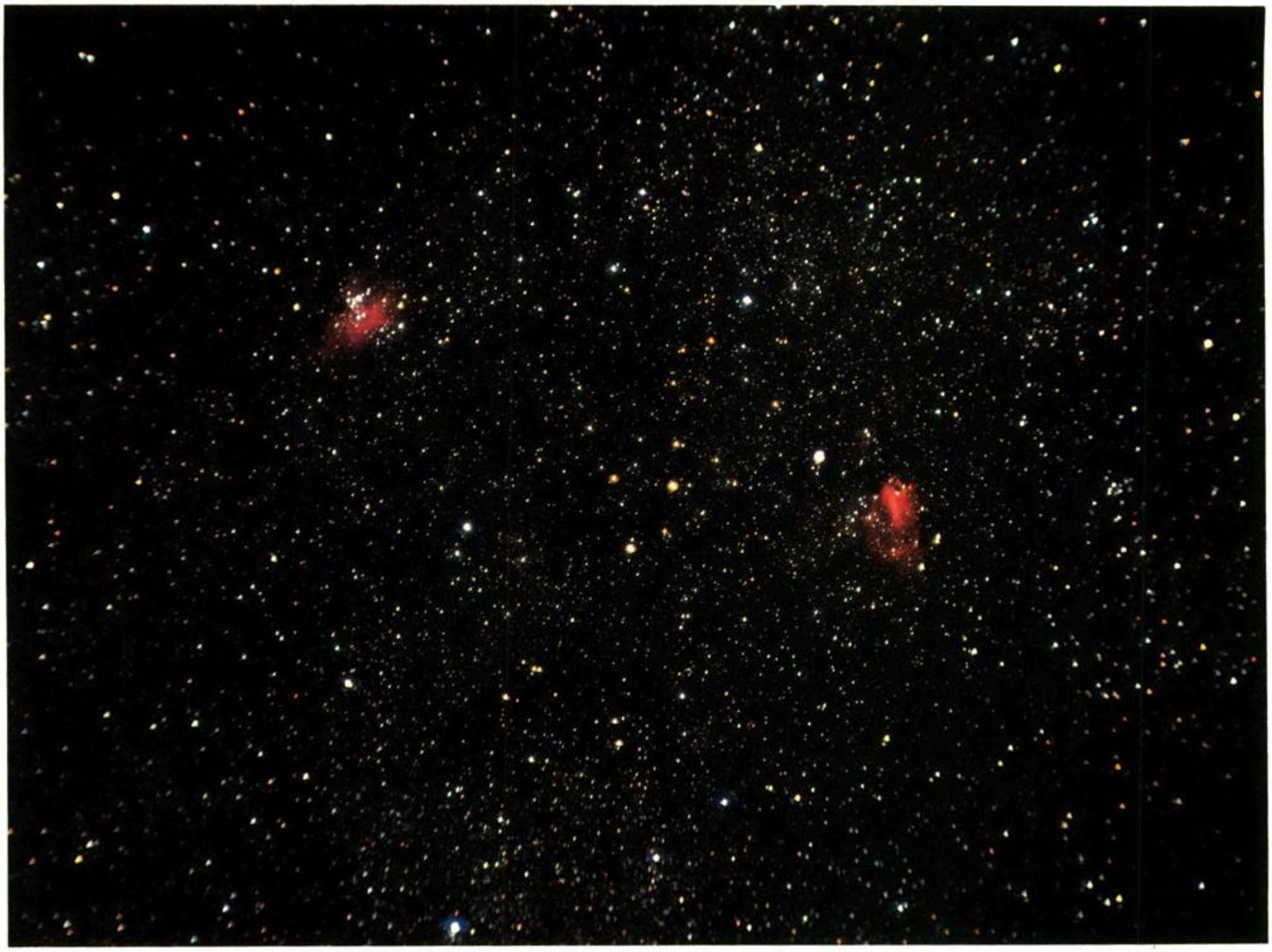


**THE NORTH AMERICA NEBULA** is captured nicely in this 40-minute exposure. All photos by Matthew F. Willson.

**THE MILKY WAY IN SAGITTARIUS** serves as the subject for this 10-minute exposure made with a 50mm f/2.2 lens.

Summer is rapidly approaching and with it come some prime targets for backyard astrophotographers. Many nebulae and clusters and, perhaps best of all, the riches of the summer Milky Way will be making their appearance over the next few months. If you want to capture these vistas there's no better way than to piggyback a camera and lens onto your telescope.

Piggyback astrophotography is relatively easy and inexpensive if you already own a camera and an equa-



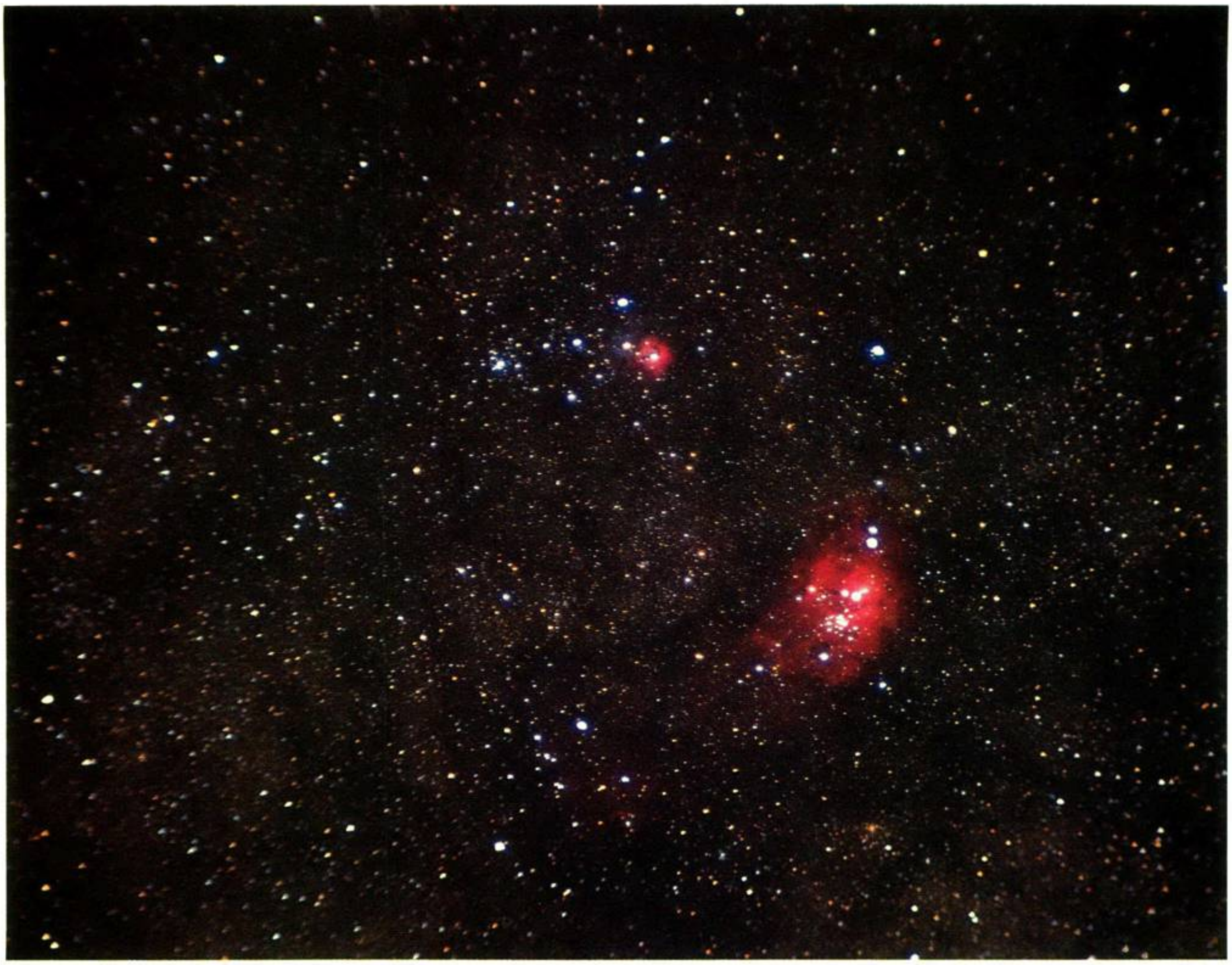
**THE EAGLE** (left) and Omega nebulae dominate this 25-minute exposure of the Serpens/Sagittarius border.

**FAINT WISPS OF NEBULOSITY** surround the star Gamma Cygni in this 40-minute exposure.

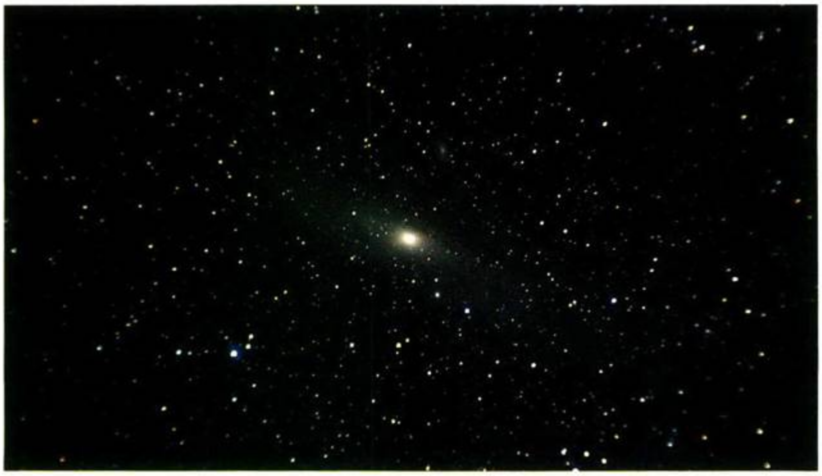
torially mounted, clock-driven telescope. All you do is mount your camera on the telescope tube, with either a bracket that bolts to the camera's tripod socket (an accessory sold by many telescope manufacturers) or by fashioning your own out of wood or aluminum. Because you guide the photos by centering a moderately bright star in your telescope's eyepiece, you don't need a separate guidescope or off-axis guider. And unless you use a lens with a focal length greater than about 200mm, your guiding doesn't have to be extremely precise.

You want to use a basic camera that can take time exposures (indicated by a shutter setting of B or T) and has a mechanical shutter so the batteries don't drain during long exposures. You'll also want a cable release to minimize vibrations when you trip the shutter. Most any camera lens that you own will do, though zoom lenses generally don't perform as well off-axis and tend to be photographically slower than comparable fixed focal length lenses. You'll reduce coma, which blurs images toward the edge of the field, if you stop the lens down from wide open. It's more than worth the extra exposure time to shoot at a setting of f/2.8 or even f/4 than to opt for f/1.4 or f/2.

It's even possible to get excellent results without using a traditional camera lens. I took all the photos in this article, with the exception of the Milky Way shot (page 71), with a 300mm f/3.7 finder scope that cost about $200. Although the finder scope is inconvenient for terrestrial photography, it's nearly perfect for astrophotography. And a top-quality, name-brand camera lens with the same focal length would easily cost



**THE LAGOON NEBULA** (M8) in Sagittarius reveals a wealth of detail in a 35-minute piggyback photo.



**THE ANDROMEDA GALAXY** (M31) is the finest galaxy in the northern sky for piggyback astrophotographers, as this 40-minute exposure demonstrates.

twice as much. Although a camera lens is easier to focus and has adjustable f/stops, these features aren't really necessary. The slight coma effect near the edge of the field isn't enough to bother me, though I could reduce it by putting a black-paper mask over the lens.

The film you choose is largely a matter of personal preference. Faster films require shorter exposure times and thus less time at the eyepiece guiding, but they typically have coarser grain. Experiment with a range of exposure times between about five and thirty minutes. Use those results to judge what combination of film and exposure time works best for a given object.

For the color photos in this article I used hypersensitized Fujichrome 100; the black-and-white photo was shot with hypered Technical Pan 2415. I like the beautiful color and very fine grain of Fujichrome 100. I also prefer slide film because it costs much less to develop slides than to get a decent custom print. If I want a framed print of one of my slides I can always have one made from the transparency.

Piggyback astrophotography is a pleasure because it's so easy to get started in with a relatively small investment. But the reward is in the stunning astrophotos you can produce. Why not give it a try soon? The summer sky beckons. ☐

---

*Matthew F. Willson is an avid astrophotographer from Littleton, Colorado. His most recent article, "Make Your Own Black-and-White Prints," appeared in the March 1988 issue.*

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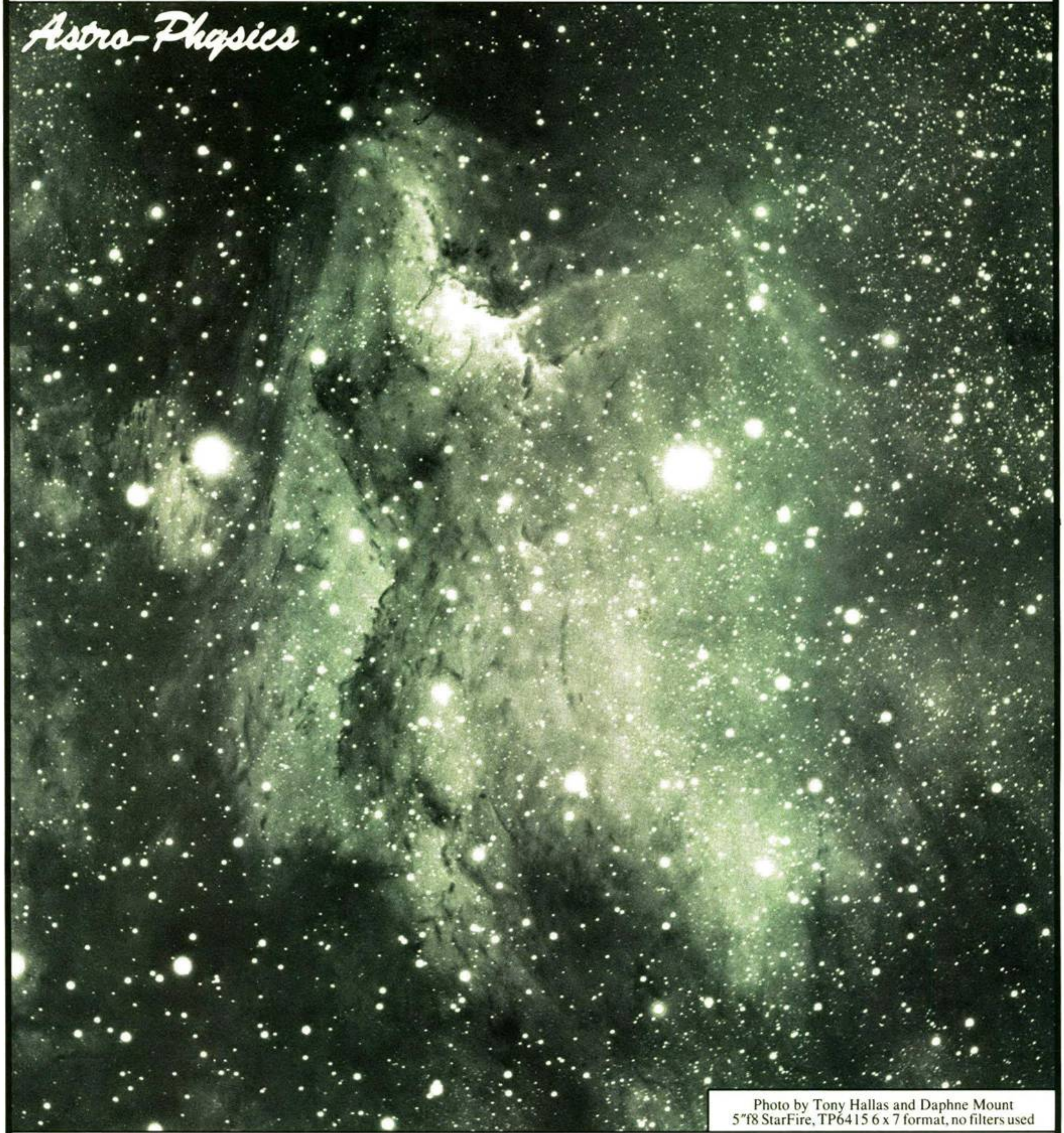

Photo by Tony Hallas and Daphne Mount
5"f8 StarFire, TP6415 6 x 7 format, no filters used

## TECHTALK What is a high resolution lens?

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To achieve this level of performance requires high surface accuracy. Instead of fancy aspherics, the StarFire lens uses an all spherical design to achieve spherical aberration correction and negligible sphero-chromatism. This assures the smooth surface profile so important to crisp image detail and high contrast. Surfaces are checked by test plate interferometer methods, and the final figure and color correction is verified *on a double* pass autocollimator. Because of the all spherical design and our ability to test each surface separately, we can guarantee a high resolution lens every time.

This stunning photograph of the Pelican Nebula in Cygnus was taken with our 5" StarFire on the 800 mounting. Guiding was done with a separate 3" guidescope. The Pelican area shown above is approximately 1/3 of the original 6 x 7 format. This reproduction can only hint at the incredible detail visible on the full negative. Tony remarked that even in 16 x 20 enlargements, the smallest stars remain only pinpricks, and some close doubles require a 40" print to adequately resolve. This is only one of many photos that we have received from Tony that show the level of detail that a precision lens can record on hypered fine grain film.

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# KEEPING WATCH ON JUPITER

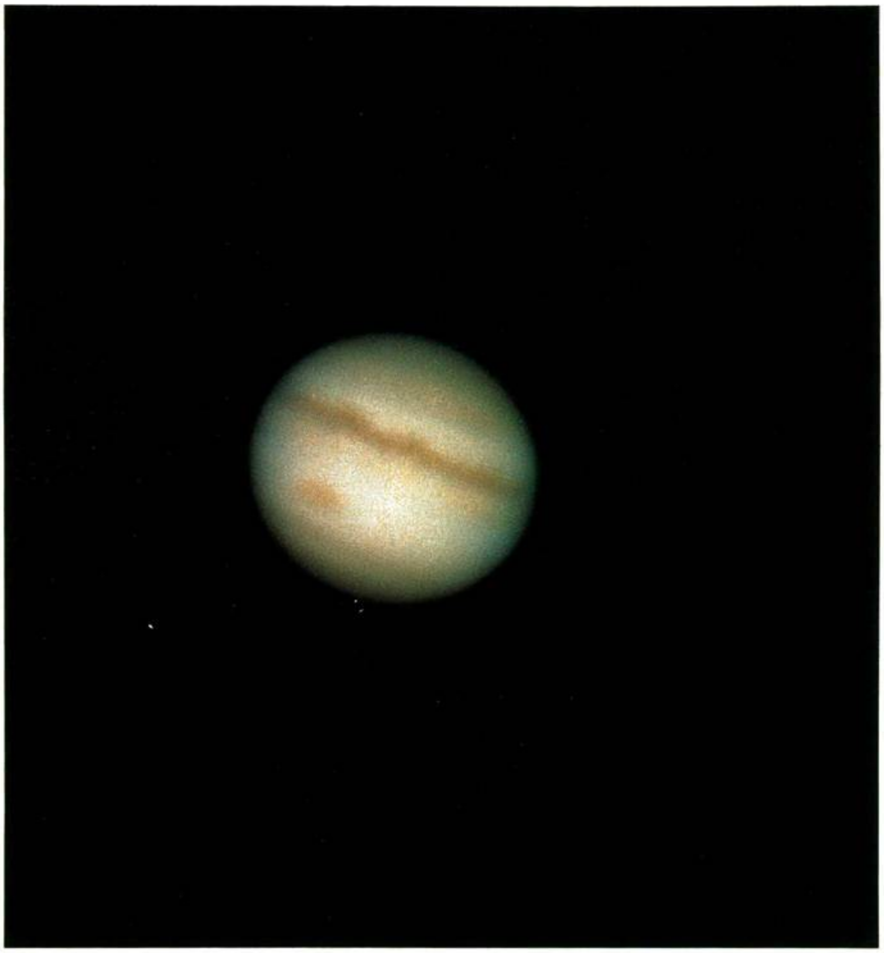
The final months of the 1980s brought a great show from the planet Jupiter. On July 19, Guy M. Hurst of Basingstoke, England, became the first to report a major brightening of the planet's dark South Equatorial Belt. Other observers in England and Spain spotted this unusual phenomenon at about the same time, and hundreds of observers all over the globe saw it soon afterward.

"Planets do things! That's why planetary observing is rewarding," wrote Steve Lantz of Englewood, Colorado. "In Jupiter's case, I can recall seeing two prominent equatorial cloud belts since the 1960s, even in the most modest telescope. But recently, as many observers have noted, the once prominent South Equatorial Belt has faded to virtual invisibility. In addition, the Great Red Spot has shifted considerably in longitude and may be darkening substantially. Such major changes on this huge world challenge the imagination to picture the energies and forces involved in moving around vast quantities of atmospheric matter."

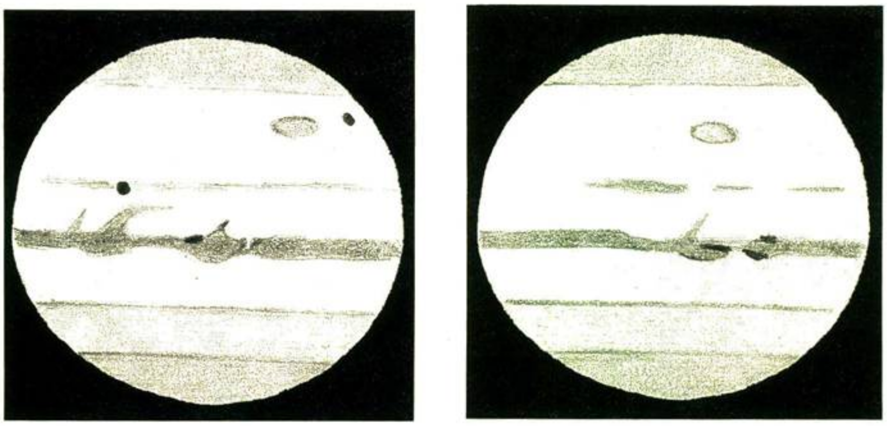
Lantz has been monitoring Jupiter almost daily since August 1989. "I first got wind of the changes in August when I attempted to view some planets during the daytime," said Lantz. "After acquiring Venus in my scope, I found Jupiter and was stunned when I saw only one cloud belt. For a while I attributed the missing cloud belt to poor daytime seeing. But a late night session in early September confirmed the disappearance of the South Equatorial Belt.

"As of early December, the belt is still very faint," said Lantz. "Curiously, I've had the best luck seeing traces of it with a #25 red filter, suggesting that the remaining features are either blue in color or that the red filter preferentially improves seeing. The Red Spot all but disappears under red light but is much more prominent in blue light. While I cannot directly detect much color in the spot, the differing response through the colored filters clearly suggests that indeed the Great Spot is red.

"On several occasions, the North Equatorial Belt has appeared active, with all kinds of different cloud structures. The sketches I made of the planet this autumn show that changes can occur after only a few minutes. It's anybody's guess when the South Equatorial Belt will return to prominence. We'll just have to keep on watching."



**JUPITER'S RED SPOT** was visible last winter, but the planet's South Equatorial Belt remained elusive. Photo by Gregory Terrance.



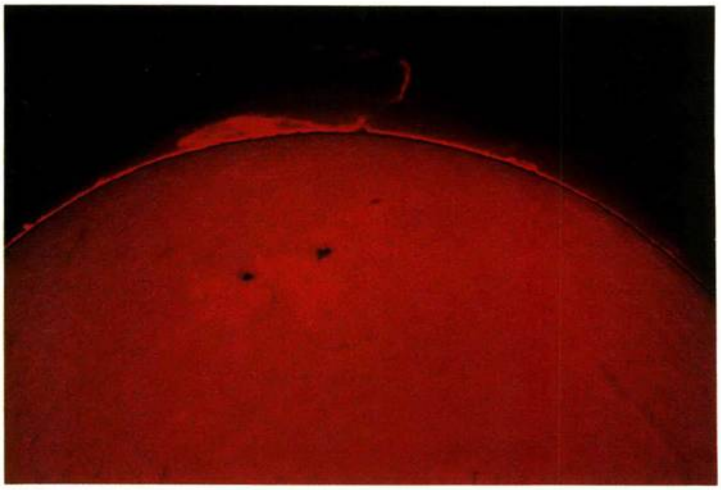
**CHANGING CLOUD FEATURES** characterize these sketches of Jupiter made fifteen minutes apart on November 11, 1989. The sketch at left shows the shadows of Io and Europa; while that at right shows altered cloud bands. Sketches by Steve Lantz.

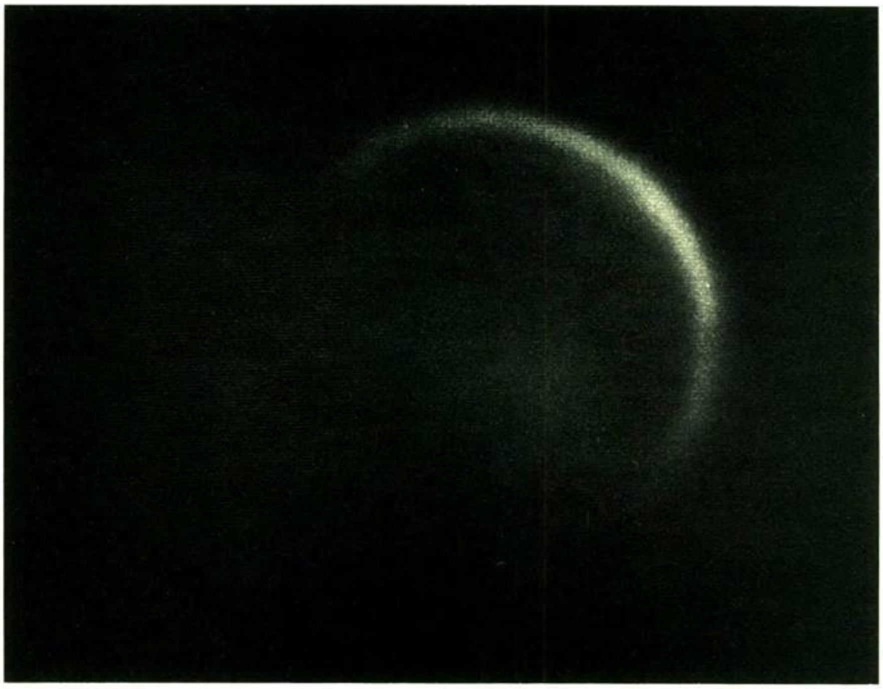
# PAINTING A PORTRAIT OF M31

The graceful beauty and large range of brightness of the Andromeda Galaxy is difficult to capture on film. Backyard astrophotographers who record this galaxy are in effect painting its portrait with the light of distant stars. Tony Hallas and Daphne Mount's dazzling, long-exposure photograph of M31 (opposite page) wins this month's $100 "Best Astrophoto" award. They used a 6-inch f/8 refractor, hypered Tech Pan 6415 film, and a 150-minute exposure.

Much closer to home are comets Austin (below, left) and Aarseth-Brewington (bottom). Jeffrey L. Jones captured Austin in a 20-minute exposure on January 24. Ronald E. Royer photographed Comet Aarseth-Brewington with an 18-inch f/7 reflector, IIIa-F film, and a 7-minute exposure.

Vladimir Vudler's photograph of a solar prominence (below, right) is a composite, consisting of separate photos of the prominence and the solar disk combined in the darkroom.





**ONLY 10° FROM THE SUN,** skinny Venus shines with a disk only 1.4 percent illuminated on January 13. Maurice Gavin captured the planet using a video camera.

### *THE DICHOTOMY OF VENUS*

What's the favorite game for longtime observers of Venus? There could only be one all-around choice: guessing the time of dichotomy. As the planet passes through its sweeping changes in phase, diehard Venus observers enjoy figuring out exactly when the planet is 50 percent illuminated and 50 percent dark. "Since the eighteenth century astronomers have commented that this moment does not correspond to the date predicted from the planet's ephemeris," said Marc A. Gelinas, of Montreal, Quebec. "A natural way to determine the date of dichotomy is to observe the planet daily and graph the results," he explained.

Proposed by John McCue and John McNichol of the British Astronomical Association, an experimental method has been employed with great success by a team of Canadian observers. "If the Venusian phase is plotted over several weeks, we can trace a curve through the points and mathematically determine the point of dichotomy," said Gelinas.

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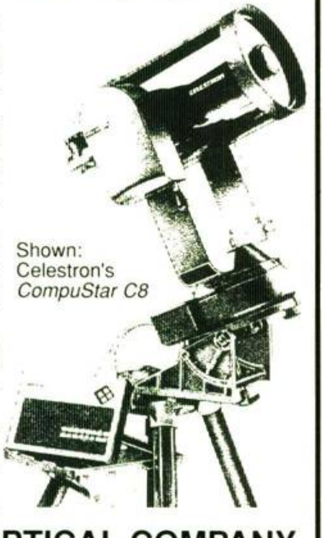
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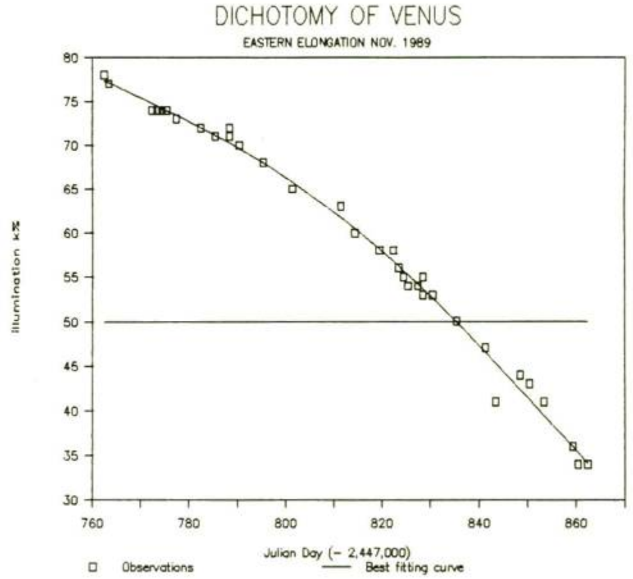
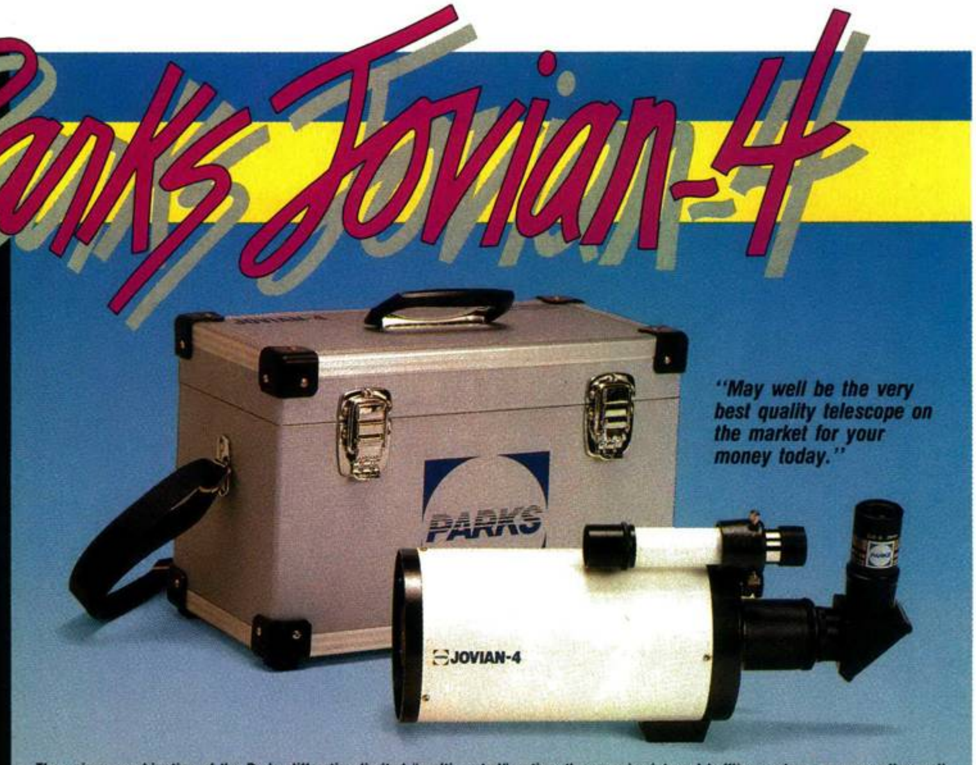


**THE DICHOTOMY OF VENUS** can be determined by plotting the percentage of disk illuminated against date, fitting the best curve to the observations, and determining on what day the planet was 50 percent illuminated. Chart by Marc A. Gelinas.

During a 100-day period between August and November 1989, Jean-Francois Viens, Todd W. Lohvinenko, and Gelinas gathered thirty-four observations of Venus in white and yellow light. They plotted the information on a computer, used a curve-fitting program to link the data, and easily determined where the curve crossed the axis showing 50 percent illumination. The Canadians found that the most recent dichotomy of Venus occurred on November 4.74, 1989 UT, an anomaly of 3.02 days before the predicted date of November 7.76 UT.

"The more observers and data points used, the better," said Gelinas. "This tends to minimize errors. Except for two micrometer measures, our data came from visual comparisons of Venus with calibrated, pre-drawn disks and from measures on drawings made at the eyepiece. The telescopes used ranged from 4 inches to 10 inches in aperture. By computing the margin of error of each observation, we were able to estimate that our result is accurate to plus or minus 0.12 days.

"Such a project is extremely rewarding," reported Gelinas. "It involves only simple equipment, perseverance, and strictness, making it perfect for amateurs. You can bet we 'll do the same work for the morning dichotomy of Venus in March and April." — *David J. Eicher* □



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## Forum

# CONFESSIONS OF A NEOPHYTE

One word describes my introduction to telescopes, astronomy, and the whole big universe — INTIMIDATING!

It's been almost two years since I got involved in astronomy and I think it's time to come clean. Maybe my confession will give hope to other beginners out there who have no idea what they're doing.

I had no intention of getting into astronomy; it was just a fluke. Our last child had left the nest and my husband and I were looking for some excitement to add to our lives. We soon found that anything that interested us was either too tiring, too expensive, or too fattening. It didn't take long for us to fall back into our old rut. Until one fateful day.

I went to school in the days when it was deemed sufficient to teach you about the Sun and Moon. If you got lucky, they threw in the Big Dipper.

A simple appreciation for what a Full Moon can do to a romantic evening satisfied my astronomical interests until one day when I casually strolled into a garage sale and changed my life. In the middle of the garage, surrounded by heaps of kids' clothes, old books, and broken tools, was a telescope. A 3-inch refractor, to be precise.

Now why this thing should have caused my heart to flutter in excitement is something I still can't explain. Maybe I was flashing back to a time before radio and TV when all there was to do in the evening was watch the stars. Anyway, in that instant all I knew was that I just had to have that telescope.

In the madness of the moment the deal was done. I was now the proud, if confused, owner of a telescope almost as old as I. Yet that innocent looking contraption started a love/hate relationship I almost regretted.

They say ignorance is bliss. Not true! That monster came equipped with an equatorial mount, setting circles, and *no instructions.* It was for sale because its owners couldn't figure it out, and it seems they were only the last in a long line of baffled prior owners.

Did I let this stop me? No way. I was determined to master the thing. After all, I had spent half a lifetime running vacuums, dishwashers, microwaves, and just recently, computers. C'mon, how hard could a telescope be?

My husband watched in stunned silence as I struck my deal. When he finally found his voice, he had only one question: "Are you nuts?"

I smiled smugly as we loaded the scope in our car. "Trust me," I said. "We're going to have a ball with this thing."

That very night I took my new treasure out to the backyard to roam through the universe. Oh, brother, was I in for a few surprises.

My first problem was getting the blasted thing pointed at the sky. It seemed to be stuck in one position — down. With my big bright flashlight I studied the situation. It seemed logical that all those widgets had a purpose. I bravely turned one — Whoops! Well, I'll be darned. On to the next one — Oh, oh! (Hint to beginners without an instruction manual: never, ever, touch the big widget on the bottom in the dark. It takes *months* for a whole fingernail to grow back.)

At this point I sternly pushed away all thoughts of how much fun my husband must be having at the weekly bingo game and decided to do some more "situation" studying. It finally dawned on me to point the tube at the sky and turn all the widgets again. Tah-dah! Success!

The sellers of this wonderful instrument had graciously shown me the only feature they had ever figured out. So I took the little black thing with 6mm on it and stuck it into the end of the scope. I then began my excursion to the stars.

The only problem was I couldn't see anything. I've since learned about the wicked people behind big desks who sell high-power eyepieces with small-aperture telescopes. They're the same evil trolls who included the Sun filter that screws into the eyepiece which I innocently let my grandchildren look through one sunny afternoon.

Wondering what all the hoopla about astronomy was, I shoved the scope around until I saw light. I was looking at the Full Moon! Not knowing about focus knobs, I was completely thrilled with my out-of-focus view. I spent many happy moments studying a bright blur.

I remember wondering, as I put everything away for the night, why they built telescopes so close to the ground. My neck was killing me. (It was my husband who later found the star diagonal lurking in a corner of the box and figured out how to use it,

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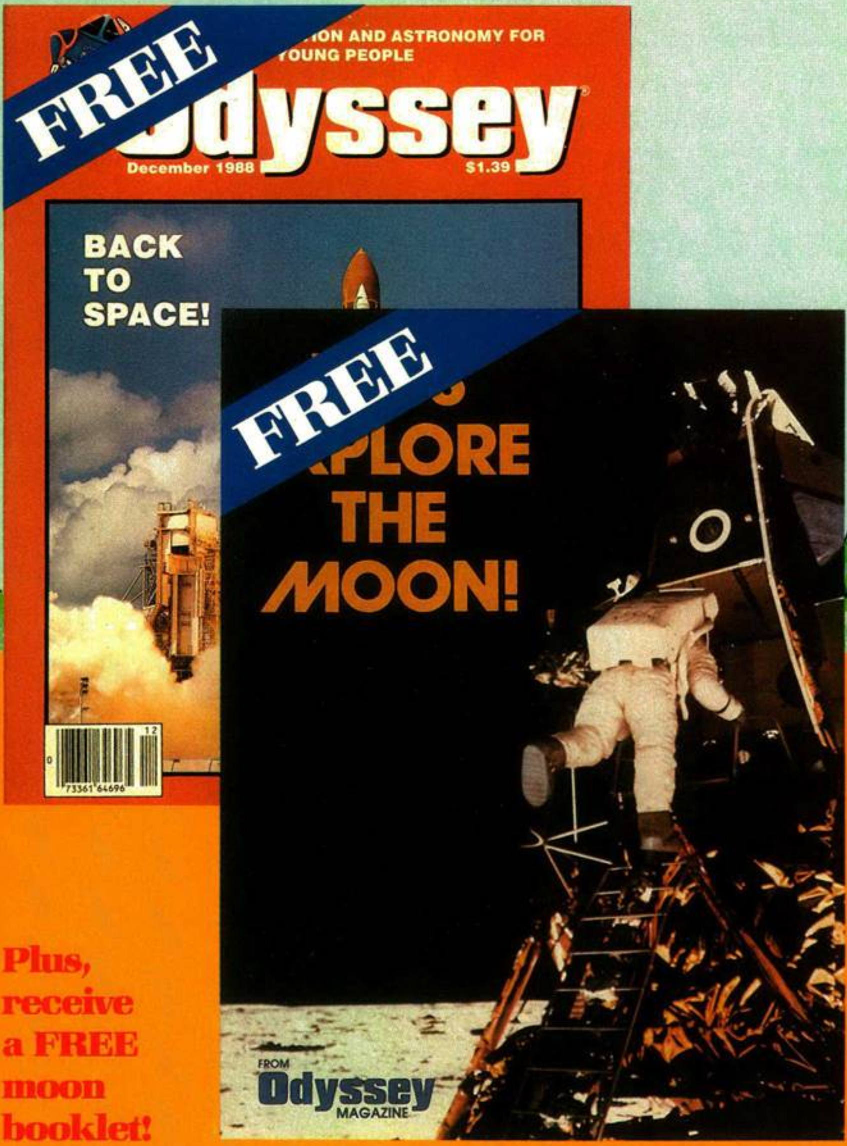

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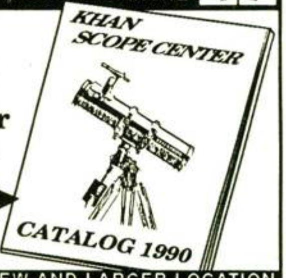

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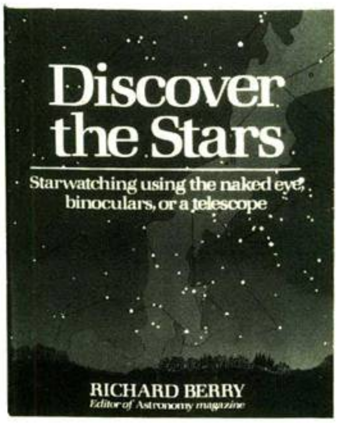
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chuckling all the while.)

I could hardly wait to tell my husband how beautiful the Moon is up close. His response, when he got home from bingo, was "Uh, huh."

The next night I talked him into looking. I had my trusty flashlight on, so I didn't miss the look he gave me as he straightened up. "There's nothing there." His I-told-you-so tone made me look. He was right. Nothing.

He scrounged around in the box and came up with something that had 12.5mm written on it. Then this man, who can get lost two blocks from home, swung the scope around and zeroed in on what we later learned was Arcturus.

Keep in mind we still didn't know about focus knobs and had no idea what a star was supposed to look like through a telescope. But oh, that star! We were totally awed and enchanted by how big and shimmering it was. If you want to see what we looked at for more than a week, pick any star and rack it out of focus.

Fat, fuzzy stars soon began to pall, however, so I made a few phone calls and learned about star parties. To protect the innocent, I won't say where we went. (We still have to live in this town, after all.)

Armed with an invitation to the next party I went to work on our scope. I didn't want to be ashamed of our nice, but slightly worn telescope, so I stuffed newspaper into all the openings and spray-painted it. It turned out pretty nice. (Hints, etc., part 2: Windex removes wet paint from glass, but paper towels leave a lot of lint.)

The sky was clear when the big night arrived. We went to our first star party, but it was so intimidating that it was almost our last. Scattered around the viewing area were telescopes that looked as if they could only have come out of the lab of a mad scientist. To be perfectly honest, we weren't even sure some of them *were* telescopes. My husband looked at me and said, "We're both nuts!"

We wandered around as twilight deepened and eavesdropped a little. That was a mistake. It was utterly discouraging to hear so many incomprehensible things. "Let's get the Dumbbell Nebula." "I had my mirror refigured and it's 1/20 wave." "What's the transit time of the Red Spot?"

We were too shy and embarrassed to intrude on their foreign world so we walked (slunk was more like it) back to our car.

We waited until it was completely

dark before we unloaded our itsy-bitsy telescope. To be frank, we were ashamed to have anyone see it. The poor thing looked like a Chevy at a BMW convention.

I held the flashlight while my husband began to set up. The next thing I knew a voice boomed out, "Kill the white light!" Now we really had a problem. We weren't familiar enough with our scope to set it up in the dark. We knew with certainty it was a lost cause, so we put the telescope back in the car, and spent the next few hours enjoying the unusually (for us) dark sky with our naked eyes.

We were thrilled as the evening went on, and we were able to look through some of the other scopes. By carefully snooping around we finally learned about focus knobs and red flashlights. Our first look at a focused star was wonderful. We saw and heard just enough to make us determined to figure out this strange world of astronomy.

We spent weekends over the next several months in bookstores and the library. For the longest time the more we read, the more confused we became. Looking back I realize that in trying to absorb everything at once we couldn't seem to find a starting point.

It wasn't easy, but finally we mastered the operation of our scope (except for the setting circles). From our home the Big Dipper is easily seen and we decided to tackle it as a beginning to understanding the night sky. Thankfully, it was a smart decision. We were able to work our way out from the Dipper and before long other constellations became familiar territory to us.

Last year we sold our scope. The dreaded disease of backyard astronomers had hit us — *biggertelescopitis.* We bought a 12 1/2-inch reflector. Granted, horsing it around has introduced me to my sciatic nerve, but I love it.

To other beginners who are wondering if astronomy is worth the expense and frustration, I can only say one thing: *yes!* Hopefully the journey you take won't be as rough as ours, but if it is, remember what's awaiting you. Magnificent galaxies, glowing nebulae, and the thrill of knowing that for a little while you can leave Earth and travel among the stars. That makes it a journey worth taking at any cost.

So if you're someone with an old mothballed telescope in your attic or garage, get it out again. As you look through it remember you are one of the lucky few who can reach out and touch the edge of infinity. — *Karen Saunders* ☐

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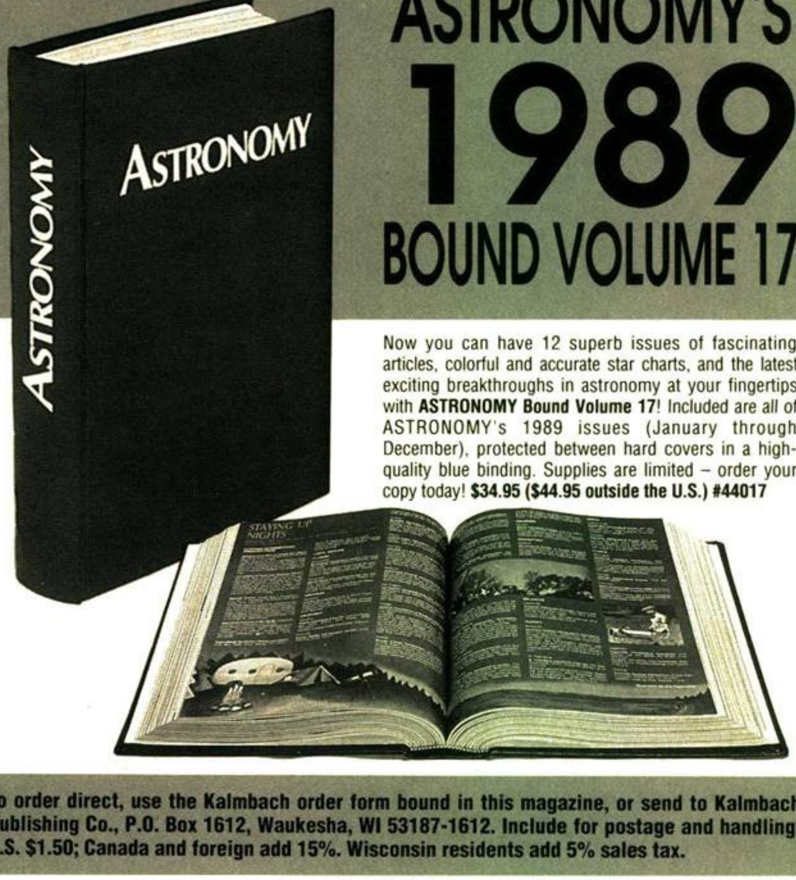

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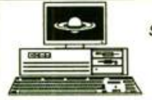

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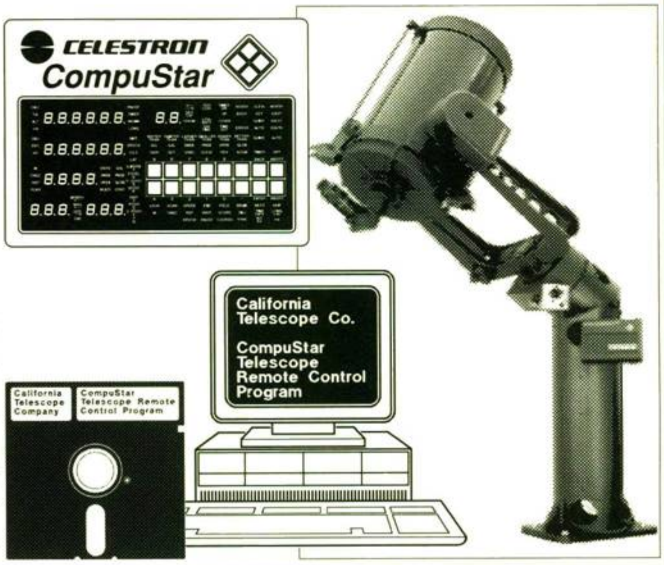
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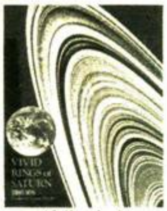

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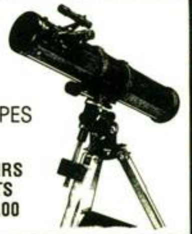

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# THE BIGGEST GALAXY BOOK EVER

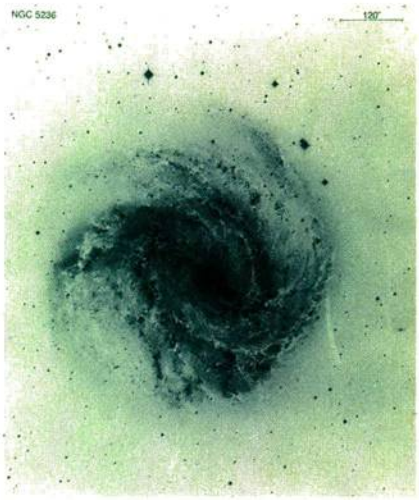
*Atlas of Galaxies Useful for Measuring the Cosmological Distance Scale* by Allan Sandage and John Bedke, (NASA, 1988; Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402-0001, stock number 033-000-01020-6), hardbound, 100 pages, $80.00.

Well, what if you don't *care* to measure the cosmological distance scale, is this book still worth it? You tell me: The atlas contains negative prints (black stars on a white background) of 322 spiral galaxies taken between 1949 and 1985 with the Hale 200-inch reflector of the Palomar Mountain Observatory and the du Pont 100-inch reflector at Las Campanas Observatory, Chile. Many of the galaxies in the atlas, including members of the Virgo Cluster, are bright enough to be observed in small telescopes.

Deep-sky observers with large telescopes may want to compare their telescopic observations to the photos. Supernovae hunters may find some of the photos useful as a comparison chart of field stars. Bear in mind, though, that this book is primarily designed as a tool to aid researchers in calibrating the luminosities of primary and secondary distance indicators in an effort to establish the cosmological distance scale. Astronomers will use these photos to look for Cepheid variables, for example, which the *Hubble Space Telescope* should be able to resolve in a number of galaxies. (In fact, the images obtained with the *Space Telescope* will have approximately 10 times the resolution of these photographs.)

Galaxies were selected for the atlas using three criteria. First, the galaxies had to have a low surface brightness so distance candidates in the disk — bright stars and HII regions, for example — would not compete with glare from the galaxy's overall brightness. Second, the spiral arms had to be easily distinguished and resolvable into stars. And third, the resolution requirement meant that galaxies had to lie within a distance of about 40 megaparsecs, or roughly 130 million light-years.

Consequently, you won't find all of your favorite galaxies in the atlas. M31 is not included since its distance is already well established. But there is a strikingly beautiful photo of M33 and one of M81. Other popular galaxies include M51, M74, M95, and M101.



**NGC 5236 AS IT APPEARS** in the *Atlas of Galalxies.*The actual page size is 16" by 20".

The atlas is quite large, physically. You've heard of coffee table books? Put legs on this book and it could *be* a coffee table! It measures 16" by 20" when closed, and when open spreads over two-and-a-half feet across. It's not exactly the kind of book you can cozy up to. But because of its size, and because negative prints show more detail than positives, you'll see galaxies as you've never seen them before: stars, HII regions, and dust lanes. The full-page photos are real eye-poppers and, fortunately, are fine-grained enough to withstand scrutiny under a magnifying glass.

If you're not a research astronomer or a supernova searcher, I don't know what you can do with a book like this other than merely possess it. But if you love to study grand-scale images of galaxies, you'll want to build an addition on to your bookshelf for this

## SOUTHERN SKY GUIDE

*The Southern Sky: A Practical Guide to Astronomy* by David Reidy and Ken Wallace, (Allen and Unwin, 1988), ISBN 0-04-300094-0, softcover, 182 pages, $22.50.

Reidy and Wallace have written a practical-level guidebook to the southern sky, which includes a bit of astrophysics thrown in here and there for good measure. Major topics include naked-eye and binocular observing, choosing a telescope, observing techniques, astronomical terms, and how to observe planets, stars, and deep-sky objects. A chapter describing interesting celestial objects, many of which can be seen from Northern Hemisphere locales, is also included along with corresponding sky charts.

Unfortunately, the graphics in this book are not too hot. Many of the black-and-white photos of deep-sky objects (no color photos are used) are of poor quality and reproduced too small. Moreover, the photographs in the chapter on interesting astronomical objects don't appear on the same page as their description, which is confusing. Finally, the sky charts at the back of the book are pinched and presented in different field sizes so that you often need a detailed sky atlas to get your bearings. Although much of the book's content is sound, the presentation makes me question the $22.50 cost, especially for a softcover book. — *Jeff*

## CAMERA TRACKERS

*Handbook for Star Trackers: Making and Using Star Tracking Camera Platforms* by Jim Ballard, (Sky Publishing, 1988), ISBN 0-933346-47-6, softcover, 124 pages, $9.95.

At last here's a book to satisfy those inventive astrophotographers who are as handy with a saw and carpenter's square as they are with a camera. Ballard, an experienced astrophotographer, tells you how to construct simple tracking platforms for 35mm cameras that are capable of either manually or automatically following the stars for minutes or hours. These devices can be constructed from wood, hinges, screws, and small electric motors — parts easily found in most hardware and electronic supply stores. Ballard's book includes a variety of camera-tracker designs and tips on shooting wide-field astrophotographs. —*Jeff Kanipe*

## BOOKS RECEIVED

### History

*The Story of Physics* by Lloyd Motz and Jefferson Hane Weaver, (Plenum Press, 1989), ISBN 0-306-43076-2, hardcover, 412 pages, $24.50.

*Under Capricorn: A History of Southern Hemisphere Astronomy* by David S. Evans, (Adam Hilger, 1988), ISBN 0-85274-384-X, hardcover, 376 pages, price unavailable. ☐

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***The Planetary System,*** (Astronomical Society of the Pacific, 390 Ashton Avenue, San Francisco, CA 94112, (415) 337-1100), 100 slides plus booklet, $97.95.

When their interest in astronomy becomes known to family and friends, many people find themselves being asked what the space program is all about. In such a situation it would be a real help to have on hand a collection of slides to haul out for an impromptu talk on the solar system.

*The Planetary System* slide set is just such a social lifesaver. Its 100 slides were chosen with the guidance of David Morrison, a well-known planetary scientist. The set has at least one photo of every major object in the solar system and covers all the major satellites as well. Comets include West and Halley, and asteroids are exemplified by Phobos and Deimos, the two moons of Mars. (This latter may not be totally correct scientifically, but they are the closest known equivalents.) Pluto and Charon are shown in a computer-calculated model derived from the recent series of mutual eclipses and occultations.

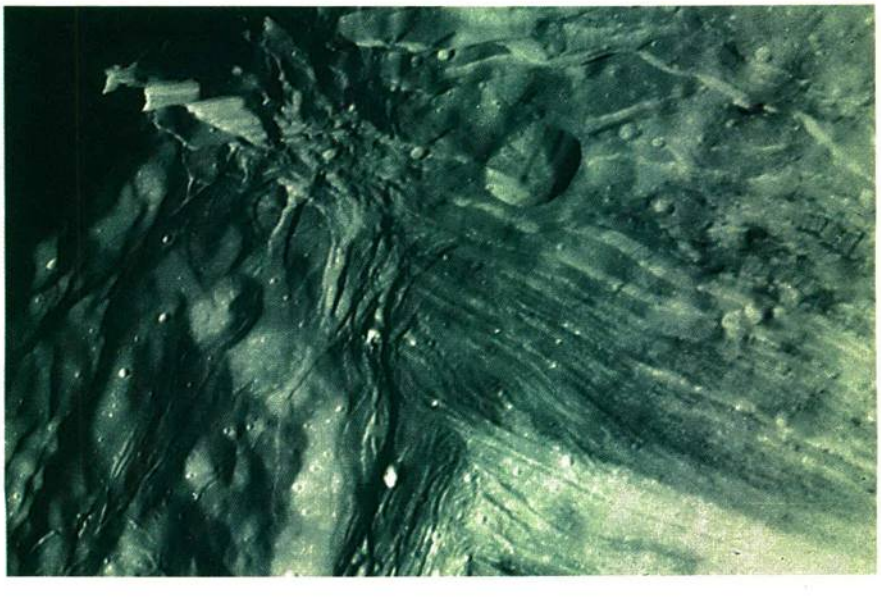
About two-thirds of the pictures are in color, though in many cases the color is computer-enhanced or arbitrarily chosen to reveal some kind of detail. The color reproduction in our review set was excellent — we found no cases of lunar craters with blue or green shadows, for example.

The set comes with a 42-page booklet that contains one- or two-paragraph captions for each of the photos, tables of data on solar system objects, an extensive reading list, and (especially helpful for educators) a series of activities and projects to help introduce elementary and high school students to planetary science.

Any long-time ASTRONOMY reader will recognize most if not all of the images in the set, so in a sense the captions aren't necessary. On the other hand, they are helpful in pointing out features of interest and provide a larger perspective for understanding the pictures. The only image for which the caption is really essential is the radio image of Jupiter's inner magnetosphere "seen" at 21-centimeter wavelength.

The source for most of the photos is NASA's vast archive of planetary images, but there are interesting and significant exceptions. For example, the Halley nucleus photo comes from the European Space Agency and a high-resolution radar map of Venus comes from the Vernadskii Institute in Moscow, via Brown University. Moreover, several of the NASA photos have been processed or mosaicked by the U.S.

**THE WHITE CLIFF OF MIRANDA**, a nine-mile-high precipice (top left) on one of Uranus' moons. From *The Planetary System* slide set.



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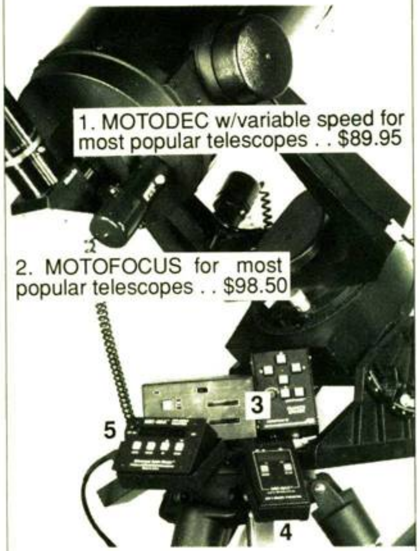

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FOR SALE — ASTRONOMY magazines, mint condition, 1987-1989 $15/year or all three years, $42. *Sky & Telescope* 1984 in binder, $20. Without binder, $15. Contact Gary A. Liberatore, 5103 Hamilton Avenue, Baltimore, MD 21206. Phone: (301) 488-6297.

FOR SALE — *Star and Sky,* 13 issues (premier issue), *Popular Astronomy,* 8 issues (premier issue), ASTRONOMY 1978-1989, complete years 1981, 1983, 1984, 1986, 1987 and 1988. Phone: (705) 786-2610.

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FOR SALE — Ed Byers precision telescope driving system, 6" x 8" gears (189 teeth, 24 x 32 dp). Worm & motor included. Never used; mint condition. Will easily drive a 16" telescope; $475/OBO. Contact David LeBlanc P.O. Box 5441, Santa Rosa, CA 95402. Phone (707) 546-8017.

FOR SALE — Meade 826C Newtonian. Includes dust covers, full aperture glass solar filter, accessory shelf, manual slow motion dec. control, V.E. Digitrak 400 drive corrector with rechargeable internal battery, eyepieces, and piggyback camera bracket. Mint condition and super optics. $1,050 firm. Contact Tom: (708) 894-3750.

FOR SALE — Astro-Physics 6" f/12 triplet refractor, Mod. 800 electronic equitorial mount, 80mm guide, 8x50 finder, custom hydraulic post with 24" riser, wheeled base. Very stable, cost $6,000, will sell at $3,500. Contact Jim Cook, 5660 Via Junipero Serra, Riverside, CA 92506. Phone: (714) 684-2224, evenings.

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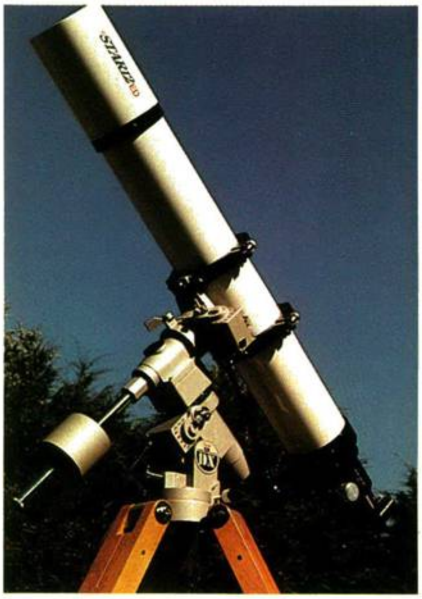
Geological Survey. This shows a healthy diffusion of research, as planetary scientists in many countries push beyond the immediate "quick look" results that are released when a mission is current.

The only drawback I see in this fine set is that its price tag will probably limit potential buyers to institutions instead of individuals. On the other hand, the price isn't too high for an astronomy club to buy a set and loan it out to members. — *Robert Burnham*



**THE STAR12 APOCHROMATIC REFRACTOR** from Astro-Physics uses a new glass type to yield color-free images at a lower cost than fluorite lenses.

### *NEW TELESCOPE*

**Star12 E.D. Apochromatic Telescope,** (Astro-Physics, 7470 Forest Hills Road, Loves Park, IL 61111; (815) 282-1513), $1,585.00 for the tube assembly, $1,012.00 for Polaris DX mount with rings and fixed-height wood tripod, $325.00 for dual-axis drives.

Use of a new type of glass has enabled Astro-Physics to construct an apochromatic (color free) lens using just two elements, without resorting to expensive fluorite lenses. The new 12cm (4.7") f/8.5 refractor uses an air-spaced high dispersion lens that has all-spherical surfaces, allowing it to be made extremely smooth and free of zones.

The Star12 comes with a 2.7-inch

focuser, 2-inch and 1¼-inch adapters, dewcap, lens cover, and foam-lined carrying case. The tube assembly weighs 11 pounds.

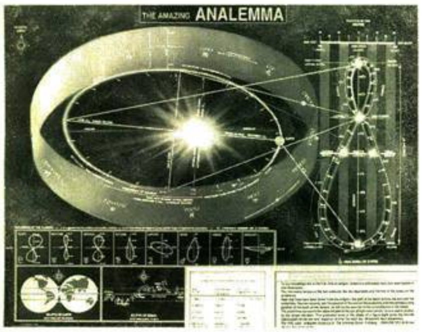
To complement the Star12, Astro-Physics offers the new Polaris DX mount, which boasts large steel shafts in both axes and a brass drive gear with a 7-arcsecond periodic error. A polar-alignment scope is built in. Options include a dual-axis motor drive that runs on 12 volts, plus a range of photo accessories. Either a fixed height or adjustable tripod is available.

## POSTERS

**The Amazing Analemma,** (Dropzone Press, P.O. Box 882222, San Francisco, CA 94188), 22" by 27" color poster, no price given.

The analemma, a tall, figure-eight shape, is the apparent path in the sky that the Sun traces during the year when you note its position at noon from any single location on Earth. Because Earth's orbit is not circular, the Sun appears to cross the sky at a rate that varies slightly throughout the year. Another way of looking at the analemma is to see it as the graphic representation of the varying error, called the equation of time, that must be corrected for if a sundial is to read time accurately.

*The Amazing Analemma* is a poster that "celebrates" the analemma, presenting facts about it and a brief text that stops just short of explaining what it can be used for. As a curiosity, it also shows the analemmas that the Sun would trace if observed from other planets in the solar system. □



***THE AMAZING ANALEMMA*** is a poster that partially explains this familiar figure-eight, important to sundials and navigators and usually found somewhere in the Pacific Ocean on terrestrial globes.

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# Meetings and Events

*For a complete listing of summer star parties and amateur events, see the special pull-out insert, "ASTRONOMY's 1990 Guide to Summer," in the center of this issue.*

**April 28**
**Astronomy Day.** Contact: Gary E. Tomlinson, Astronomy Day Coordinator, Astronomical League, Chaffee Planetarium, 54 Jefferson Avenue SE, Grand Rapids, MI 49503. Phone: (616) 456-3985.

**April 28**
**Astronomy Day Celebration,** Charles Hayden Planetarium, Boston Museum of Science, Boston, Massachusetts. Phone: (617) 589-0270.

**April 28**
**Astronomy Day Gathering,** The Wilderness Center, Wilmot, Ohio. Sponsored by the Wilderness Center Astronomy Club. Phone: (216) 359-5235.

**May 4-5**
**AstroFestival '90,** Roberson-Kopernik Observatory, Vestal Center, New York. Sponsored by the Kopernik Astronomical Society. Contact: Roberson-Kopernik Observatory, Underwood Road, Vestal Center, NY 13850. Phone: (607) 772-0660.

**May 5**
**Astronomy Day,** Museum of Arts and Sciences, Macon, Georgia. Sponsored by the Museum of Arts and Sciences and the Middle Georgia Astronomical Society. Contact: Astronomy Day, Museum of Arts and Sciences, 4182 Forsyth Road, Macon, GA 31210.

**May 22-27**
**The 10th Annual International Space Development Conference,** San Antonio, Texas. Sponsored by the National Space Society and the Southwest Research Institute. Contact: Carol A. Luckhardt, Southwest Research Institute, 6220 Culebra Road, San Antonio, TX 78228-0510. Phone: (512) 522-3823.

**June 30**
**You and the Universe,** Carleton University, Ottawa, Canada. A public symposium sponsored by the Royal Astronomical Society of Canada. Contact: The Royal Astronomical Society of Canada, 136 Dupont Street, Toronto, Ontario, Canada M5R 1V2.

**July 13-15**
**Symposium on Automated Telescopes and Global Networking,** Boston University, Boston, Massachusetts. Contact: Meeting Information, Astronomical Society of the Pacific, 390 Ashton Avenue, San Francisco, CA 94112.

**July 13-18**
**Astronomical Society of the Pacific Annual Meeting,** Boston University, Boston, Massachusetts. Contact: Meeting Information, Astronomical Society of the Pacific, 390 Ashton Avenue, San Francisco, CA 94112.

**July 14-15**
**The Universe in the Classroom,** Boston University, Boston, Massachusetts. Contact: Workshop Information, Astronomical Society of the Pacific, 390 Ashton Avenue, San Francisco, CA 94112.

**July 24-28**
**First European Meeting of the American Association of Variable Star Observers,** Brussels, Belgium. Contact: Janet A. Mattei, AAVSO, 25 Birch Street, Cambridge, MA 02138.

**September 29**
**Astronomy Day,** Pensacola, Florida. Sponsored by the Escambia Amateur Astronomers Association. Contact: Margret Hildreth, Escambia Amateur Astronomers, 4100 Lillian Highway, Pensacola, FL 32506. Phone: (904) 456-0078.

**October 19-20**
**8th Annual Northern Virginia Telescope Meet,** C. M. Crockett Park, Calverton, Virginia. Contact: Al Schumann, 6121 Rivanna Drive, Springfield, VA 22150. Phone: (703) 256-4777.

**October 19-20**
**Twin Lakes Star Party.** Sponsored by the West Kentucky Amateur Astronomers. Contact: Jim Boren, Land between the Lakes, Golden Pond, KY 42211-9001. Phone: (615) 232-7405 (days), (615) 232-6820 (evenings).

**July 8-12, 1991**
**Research Amateur Astronomy Symposium,** La Paz, Baja California Sur, Mexico. Contact: Corporation for Research Amateur Astronomy, P.O. Box 16542, San Francisco, CA 94116. ☐

*Please submit announcements at least four months before the date of the meeting or event.*

*When you write to organizations listed in Meetings and Events, include a self-addressed, legal-size envelope with your request for information.*

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FOR SALE — ASTRONOMY magazine, *Bio-Science, Cosmic Search,* and *Sky & Telescope* incomplete. Send S.A.S.E. for list. Contact D. Copper, P.O. Box 816, New Castle, PA 16103.

FOR SALE — Meade 2080 LX-5, dec. motor, illuminators, DGW cap, accessory case, 2" ocular, 3 eyepieces, 1 year old, mint. $1,500. Contact John Russell, 29 Sharon Lynn Blvd., Monegan Lake, NY 10547. Phone (914) 528-0722.

FOR SALE — Tele-Vue 1.8 Barlow, needs locking screw. $55. Meade 7mm research grade ortho. $35. B&L 8x50 finder with Newt. Brackets $48 for both take all three and get B&L 9mm ASP free. Contact L.J. Rose, P.O. Box 332, N. Attleboro, MA 02761. Phone (508) 695-9623, days.

FOR SALE — Celestron 8", used very little, Ploesl and other eyepieces, many extras, tripod, and carrying case. Total paid $2,100, asking price $400 or best offer. Contact Jonas Prakapas. Phone (805) 322-8105.

FOR SALE — Celestron 4" f/9, fluorite refractor. Excellent condition and optically superb. Customized with Vixen super-DX polaris mount on Meade heavy-duty tripod. Dual-drive, Celestron glass solar-filter. Telrad, padded carry-case, tripod bag, 2" adapter, image-erector, diagonal, 6mm and 25mm oculars. $2,200. Contact Ed Zuccardi, 11233 California Street No., Hollywood, CA 91601. Phone (818) 760-4963.

FOR SALE — TeleVue "Genesis" Telescope with equatorial mount and all standard accessories. Used only a few times and stored in case. Everything in mint condition. Asking $1900. Also, Emund Scientific Astroscan 2001. With all standard accessories and in mint condition. Used only a few times. $250. Contact David Chesser, 1644 SW 109th Place, #2, Ocala, FL 32676. Phone (904) 237-7456 evenings.

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# Readings and Resources

**The Coolest Stars** (page 20)

*Cycles of Fire* by William K. Hartmann, (Workman Publishing, 1987). Hartmann's chapter on the life and death of stars includes a section on red giants. The informative text is complemented by paintings of what astronomers think red giants look like close up.

**The Crab Nebula** (page 30)

*The Crab Nebula* by Simon Mitton, (Scribner's, 1978). A readable narrative on the birth of the Crab Nebula and how astronomers came to understand it.

**Solar System Chaos** (page 34)

*Chaos* by James Gleick, (Viking Penguin, 1987). A readable and engrossing survey of the whole subject of chaos.

"The Long-term Evolution of Orbits in the Solar System" by Martin Duncan, Thomas Quinn, and Scott Tremaine, *Icarus* 82 (1989): 402-18. A three-body simulation showing that most orbits between Jupiter and Saturn, and many between Uranus and Neptune, are unstable over the lifetime of the solar system. Technical.

"Numerical Evidence that the Motion of Pluto is Chaotic" by Gerald Jay Sussman and Jack Wisdom, *Science* 241 (1988): 433-7. Reports the results of the 845-million-year integration that revealed Pluto's chaotic orbit. Technical.

**Test Drive Your Telescope** (page 56)

*Build Your Own Telescope* by Richard Berry, (Scribner's, 1985). Contains a section on star testing as well as other information about telescopes useful for even the non-builder. □

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## CREDITS

*Cover:* Canada-France-Hawaii Telescope Corporation; *page 4:* Jerry Schad (24mm f/1.4, Ektachrome P800 pushed to 1600, 120-sec. exposure); *page 10:* Bruce Elmegreen (IBM Thomas J. Watson Research Center), Frederick Chromey (IBM and Vassar College Observatory), and Debra Elmegreen (Vassar College Observatory); *page 14:* J. Anthony Tyson and Richard Wenk (AT&T Bell Laboratories) and Francisco Valdes (NOAO); *page 18, top:* Jet Propulsion Laboratory, *bottom:* Richard Berry; *pages 20-23:* paintings by Paul DiMare; *page 24:* diagram based on calculations by Icko Iben, Jr., Pennsylvania State University; *page 26:* J. C. Christou and S.T. Ridgway (NOAO), C.A. Haniff (Caltech), and D. Buscher (Mullard Radio Astronomy Observatory, Cambridge, England); *page 27:* Philip Plait and Noam Soker, University of Virginia; *page 28:* Observatory of the University of Michigan; *page 30, inset:* Lick Observatory; *pages 30-31:* Philipp Kronberg, Ontario Center for Large Scale Computation; *pages 34-35:* painting by Phil Kirchmeier; *pages 36, 38:* diagrams by Martin Duncan, Thomas Quinn, and Scott Tremaine, courtesy of *Icarus* and Academic Press; *page 44:* Ivan Dryer (April 6, 1989); *page 48:* map adapted from *Uranometria 2000.0* by Wil Tirion, Barry Rappaport, and George Lovi, ©1987 Willmann-Bell, Inc.; *page 49:* map data courtesy Doug Mink; *pages 57-60:* illustrations by Thomas L. Hunt; *page 64:* David J. Eicher (8-inch f/10 SCT at 50x); *page 65:* John P. Gleason (14-inch f/11 SCT, Ektachrome 400, 45-min. exposure); *page 66, top:* Jack B. Marling (24-inch f/9 Cassegrain, Fujichrome 400, 60-min. exposure), *bottom:* Jack B. Marling (24-inch f/15 Cassegrain, Fujichrome 400, 30-min. exposure); *page 67:* Jack B. Marling (24-inch f/9 Cassegrain, Fujichrome 400, 50-min. exposure); *page 68, top:* Jack Newton (20-inch f/5 reflector, Konica 3200, 20-min. exposure), *bottom:* Lee C. Coombs (10-inch f/5 reflector, 103a-E, 10-min. exposure); *pages 70-73:* Matthew F. Willson, *page 70:* (300mm f/3.7 lens, hypered Tech Pan, 40-min. exposure), *pages 70-71:* (50mm f/2.2 lens, hypered Fujichrome 100, 10-min. exposure), *page 72, top:* (300mm f/3.7 lens, hypered Fujichrome 100, 25-min. exposure), *page 72, bottom:* (300mm f/3.7 lens, hypered Fujichrome 100, 40-min. exposure), *page 73, top:* (300mm f/3.7 lens, hypered Fujichrome 100, 35-min. exposure), *page 73, bottom:* (300mm f/3.7 lens, hypered Fujichrome 100, 40-min. exposure); *page 75, top:* Gregory Terrance (16-inch f/63 reflector, Ektachrome 200, 1-sec. exposure, December 22, 1989), *bottom left and right:* Steve Lantz (10-inch f/5.6 reflector at 227x, #25 red and #80A blue filters; *left:* November 11, 1989, between 6:40 and 6:50 UT, *right:* November 11, 1989, 7:02 UT); *page 76, top left:* Jeffrey L. Jones (8-inch f/10 SCT, hypered Tech Pan, 20-min. exposure, January 24, 1990), *top right:* Vladimir Vudler (14-inch f/11 SCT with Daystar filter, Fujichrome 100, composite of 1/125-sec. and 1/4-sec. exposures, May 29, 1980), *bottom:* Ronald E. Royer (18-inch f/7 reflector, IIIa-F, 7-min. exposure, December 20, 1989); *page 77:* Tony Hallas and Daphne Mount (6-inch f/8 refractor, hypered Tech Pan 6415, 150-min. exposure); *page 78:* Maurice Gavin (8-inch f/10 SCT with Canon ETT videocamera, January 13, 1990, 15:30 UT); *page 79:* Marc A. Gelinas.

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| MTS-SN8 8" w/LX3 Drive & Setting Circles | **899.95** | | |
| MTS-SN8 8" w/Drive & Setting Circles | **759.95** | | |

### MTS ACCESSORIES

| | | | |
|---|---|---|---|
| #788 Drive | **114.95** | #790 LX3 Drive | **344.95** |
| Setting Circles | **24.95** | | |
| #66A Dec f/SN6, SN8 | **39.95** | #66C Dec f/SN8, SC10 | **49.95** |
| #38M Electronic Dec System | **74.95** | | |
| #43 Drive Corrector & AC DC Converter | **79.95** | | |
| 6x30 Viewfinder w/Bracket | **62.95** | | |

### REFRACTING/REFLECTOR TELESCOPES

| | |
|---|---|
| **226** 60mm Altazimuth | **124.95** |
| **291** 60mm Equatorial | **279.95** |
| **312** 80mm Altazimuth | **389.95** |
| **323** 80mm Equatorial | **459.95** |
| **314** 80mm Brass | **899.95** |
| **NEW 4420** 4.5" Equatorial Reflector | **369.95** |

### ACCS for MEADE REFLECTORS/REFRACTORS

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|---|---|
| Basic Camera Adapter 1 1/4" | **34.95** |
| Variable Projection Camera Adapter 1 1/4" | **47.95** |

### SPOTTING SCOPES

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| 97E 3.5" Compl | **369.95** | 97ER | **409.95** | 97D | **329.95** |

### DEEP SPACE TELESCOPES & REFLECTORS

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## BAUSCH & LOMB

### ASTRONOMICAL TELESCOPES

### BAUSCH & LOMB DISCOVERER

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| 78-1200 Rubber Armored | **149.95** |
| 78-1817 Standard Kit w/15-45x, tripod and shoulder case | **229.95** |
| 78-1217 Rubber Armored Kit | **249.95** |
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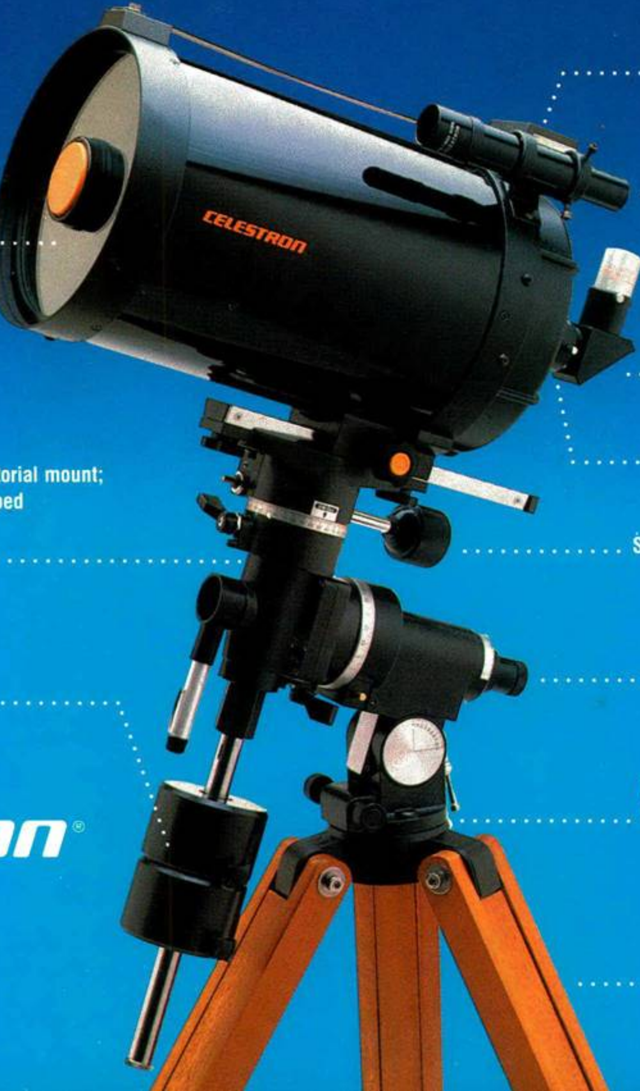
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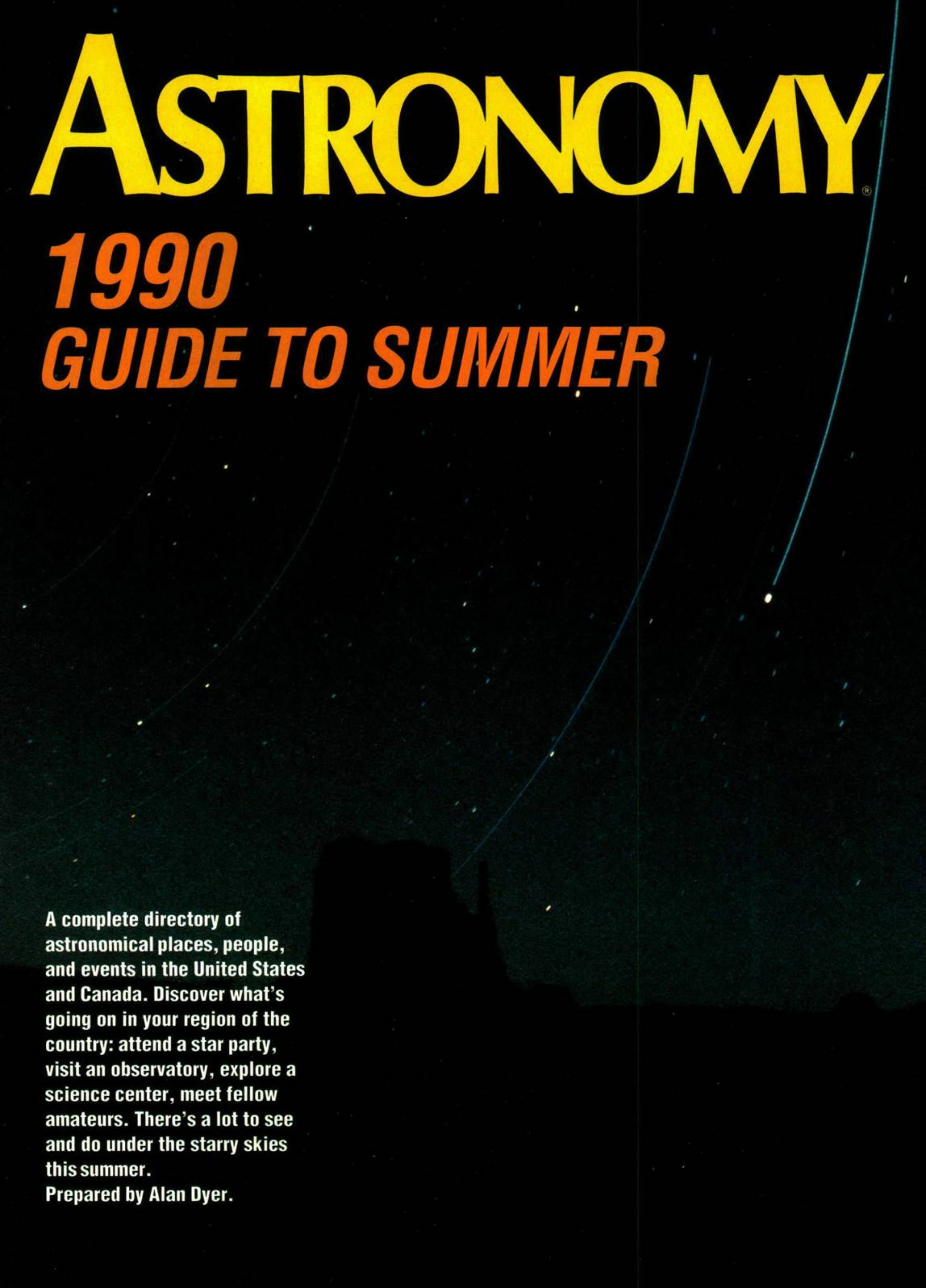
FAX: 213/212-5835
Telex: 182471

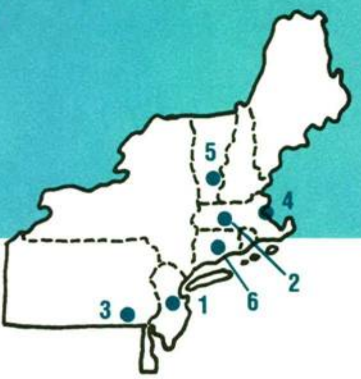


# ASTRONOMY®

## 1990 GUIDE TO SUMMER

A complete directory of astronomical places, people, and events in the United States and Canada. Discover what's going on in your region of the country: attend a star party, visit an observatory, explore a science center, meet fellow amateurs. There's a lot to see and do under the starry skies this summer.
Prepared by Alan Dyer.

## Northeast



**1** **June 15-17**
Jersey Star Quest, Rutgers 4-H Camp, Beemerville, NJ. Meals and camping packages available. RV's welcome. Contact: Amateur Astronomers' Association of Princeton, P.O. Box 2017, Princeton, NJ 08540, Greg Munro, (609) 585-9465.

**2** **June 22-24**
Astronomical League Convention (Northeast Region), Mount Holyoke College, South Hadley, MA. Contact: Springfield Stars Club, 107 Lower Beverly Hills, West Springfield, MA 01089, John E. Welch, (413) 734-9179.

**3** **June 22-24**
Mason-Dixon Star Party, York, PA. Contact: Bob Wolpert, York County Parks Astronomical Society, 42 Leader Drive, Jacobus, PA 17407, (717) 428-1965.

**4** **July 13-18**
Astronomical Society of the Pacific Annual Meeting, first East Coast meeting, Boston University. Includes "The Universe in the Classroom" teaching workshop, "The Universe Unfolding" nontechnical lectures, and merchandise exhibits. Contact: A.S.P., Meeting Information, 390 Ashton Avenue, San Francisco, CA 94112, (415) 337-1100.

**5** **July 27-28**
Stellafane, the Northeast's biggest star party, near Springfield, VT. Begun in the 1930s, Stellafane now attracts over 2,000 people a year. Contact: Stellafane, 60 Victoria Road, Sudbury, MA 01776.

**6** **September 8**
StarConn, an astronomical convention, at Wesleyan University, Middletown, CT. Talks, displays, and observing at the Van Vleck Observatory. Sponsored by the Astronomical Society of Greater Hartford, 950 Trout Brook Drive, West Hartford, CT 06119, Jay Sottolano, (203) 651-0096.

## PLACES

### CONNECTICUT

**Avon** — Talcott Mountain Science Center, Montevideo Road, 06001, (203) 677-8571. Observatory with 12" reflector. Open daily in summer.

**Mystic** — Mystic Seaport Museum & Planetarium, P.O. Box 6000, 06355, (203) 572-0711. 30' dome theater. Open daily in summer.

**New Britain** — Copernican Observatory and Planetarium, Central Connecticut State University, Wells Street, 06050, (203) 827-7852. Open Fri. & Sat. evenings only.

### MAINE

**Portland** — Southworth Planetarium, 96 Falmouth Street, 04103, (207) 780-4249. 30' dome theater, exhibits, laser shows. Open Sat. & Sun. evenings.

### MASSACHUSETTS

**Boston** — Boston University Astronomy Dept. Observatory, 725 Commonwealth Avenue, 02215, (617) 353-5700. 14" and 12" telescopes. Open every clear Wednesday night. Call 353-2630 after 5:30 p.m. Wednesdays to confirm.

**Boston** — Charles Hayden Planetarium, Boston Museum of Science, Science Park, 02114, (617) 589-0270. 60' dome planetarium theater, laser shows, exhibits, OMNIMAX® theater. Open daily in summer.

**Cambridge** — Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, 02138, (617) 495-7461. 9" Clark refractor. Public observing on third Thursday evening each month.

**Nantucket** — Maria Mitchell Observatory, Vestal Street, 02554, (508) 228-9273. Public observing Wednesday evenings July and August only.

**Springfield** — Springfield Science Museum, 236 State Street, 01103, (413) 733-1194. Exhibits, planetarium shows (33' dome), observatory (20" reflector). Open afternoons only, Thurs.-Sun.

**Westford** — Haystack Observatory, Route 40, 01886, (617) 692-4764.

**Williamstown** — Milham Planetarium, Williams College, 01267, (413) 597-2188. Open Tues. & Thurs. evenings only.

**Worchester** — New England Science Center, 222 Harrington Way, 01604, (617) 791-9211. Exhibits, public observing, planetarium shows, observatory. Open daily.

### NEW HAMPSHIRE

**Durham** — University of New Hampshire Observatory, DeMeritt Hall, 03801, (603) 862-1950. 14" telescope. Open every other Friday.

**Plymouth** — Plymouth State College Planetarium, 03264, (603) 536-5000. 20' dome theater. Open daily in summer.

### NEW JERSEY

**Mountainside** — Trailside Planetarium, Trailside Nature and Science Center, Coles Avenue and New Providence Road, 07092, (201) 789-3670. Open Mon.-Thurs. & Sun.

**Newark** — Newark Museum Planetarium, 49 Washington Street, 07101, (201) 596-6610. 30' dome theater. Open daily in summer.

**Toms River** — Robert J. Novins Planetarium, Ocean County College, CN 2001, 08754-2001, (201) 255-0343. Open Mon.-Fri.

**Trenton** — New Jersey State Museum Planetarium, 205 West State Street, CN 530, 08625, (609) 292-6333. 40' dome theater, exhibits. Open daily in summer, daytime only.

### NEW YORK

**Binghamton** — Link Planetarium/Kopernik Observatory, 30 Front Street, 13905, (607) 772-0660. Open Tues.-Sun.

**Centerport** — Vanderbilt Planetarium, 180 Little Neck Road, 11721, (516) 262-7800. 60' dome theater, exhibits, observatory (16" Cassegrain). Open daily in summer.

**Flushing Meadows Corona Park** — New York Hall of Science, 47-01 111th Street, 11368, (718) 699-0005. Exhibits, laser demos. Open Wed.-Sun., daytime only.

**Ithaca** — Cornell University Observatory, Dept. of Astronomy, Space Sciences Bldg., 14853, (607) 255-4935. 14" and 12" telescopes. Public observing Friday evenings.

**Ithaca** — Spacecraft Planetary Imaging Facility, Cornell University, 317 Space Sciences Building, 14850-6801, (607) 255-3833. Tours; can supply address lists of planetary picture suppliers but is not a distribution center. Open daily in summer 9 a.m.-4:30 p.m.

**New York** — American Museum/Hayden Planetarium, Central Park West at 81st Street, 10024-5192, (212) 769-5900. 75' dome theater, exhibits, laser shows. Open daily in summer.

**Rochester** — Strasenburgh Planetarium, Rochester Museum and Science Center, 657 East Avenue, Box 1480, 14603, (716) 271-4320. 65' dome theater, laser shows, exhibits, observatory (12" telescope). Open daily in summer.

**Schenectady** — Schenectady Museum and Planetarium, Nott Terrace Heights, 12308, (518) 382-7890. 30' dome theater, laser shows, exhibits. Planetarium open Sat. & Sun. afternoons only.

**Syracuse** — The Discovery Center, 321 South Clinton Street, 13202, (315) 425-0747. Exhibits, public observing, planetarium shows (20' dome). Open Tues.-Sun., daytime only.

**Troy** — The Junior Museum, 282 5th Avenue, 12182, (518) 235-2120. Exhibits, planetarium shows. Open Mon.-Wed. and Sat. & Sun.

**Yonkers** — Andrus Planetarium, 511 Warburton Avenue, 10701, (914) 963-4550. Exhibits, observatory. Open Wed.-Sun.

### PENNSYLVANIA

**Erie** — Erie Historical Museum and Planetarium, 356 West 6th Street,

Stellafane, near Springfield, Vermont

## CLUBS

### CONNECTICUT

**New Haven** — Astronomical Society of New Haven, P.O. Box 3005, Westville Station, 06515, Rich Asarisi, (203) 271-3830. Founded 1936, 60 members. Observatory with 10" scope.

**Oakdale** — Thames Astronomical Society, 55 Doyle Road, 06370, Kathleen Audette, (203) 859-0071. Founded 1981, 26 members.

**Stamford** — Fairfield County Astronomical Society, c/o Stamford Museum Observatory, 39 Scofieldtown Road, 06903, Charles Scovil, (203) 322-1648. Founded 1957, 96 members. Observatory with 22" Maksutov.

**Waterbury** — Mattatuck Astronomical Society, c/o Mattatuck Community College, 750 Chase Parkway, 06708, J. Lawrence Pond, (203) 575-8065.

**West Hartford** — Astronomical Society of Greater Hartford, c/o Gengras Planetarium, 950 Trout Brook Drive, 06119, Jay Sottolano, (203) 651-0096. Founded 1955, 160 members. Observatory with 17.5" telescope.

### DELAWARE

**Wilmington** — Mount Cuba Astronomical Observatory, Inc., P.O. Box 3915, located on Hillside Hill Road, Greenville, 19807, Grace Quirk, (302) 654-6407. Founded 1958, 300 members. Observatory with 24" telescope.

### MAINE

**Eliot** — Astronomical Society of Northern New England, West Hill Observatory, 80 Goodwin Road, 03903, Ray Sutton, (207) 439-4474.

### MASSACHUSETTS

**Amherst** — Amherst Area Amateur Astronomers Association, 1403 South East Street, 01002, Tom Whitney, (413) 256-6234. Founded 1984, 45 members. Observatory with 18" telescope. Public viewing on 1st and 3rd Fridays at Amherst College Observatory.

**Dover** — Amateur Telescope Makers of Boston, 8 Pond Street, 02030, Gary Walker, (508) 785-0352.

**Essex** — North Shore Amateur Astronomy Club, P.O. Box 123, 01929, Micheal McCoy, (508) 768-3494. Founded 1989, 27 members.

**Harwich** — Cape Cod Astronomical Society, P.O. Box 56, 02645, Jim Carlson, (508) 432-4316. Founded 1985, 53 members.

**West Springfield** — Springfield Stars Club, 107 Lower Beverly Hills, 01089, John E. Welch, (413) 734-9179. Founded 1948, 76 members.

### NEW HAMPSHIRE

**Keene** — Keene Amateur Astronomers, Inc., 131 Carroll Street, 03431, Paul Fisher, (603) 352-6393. Founded 1950, 35 members. Observatory with 13.1" telescope.

**Nashua** — Amateur Telescope Makers of Boston, 28 Taschereau Boulevard, 03062, Marion Hochuli, (603) 888-0141. Founded 1934, 300 members.

### NEW JERSEY

**Clifton** — North Jersey Astronomical Group, c/o Rifle Camp Park Nature Center, P.O. Box 4021, Allwood Station, 07012, Phil Conroy, (201) 523-0024.

**Cranford** — Amateur Astronomers, Inc., Union College Sperry Observatory, 07016, Roger W. Tuthill, (201) 232-1786.

**Glassboro** — Tychonian Observers, c/o Glassboro State College, Dept. of Physical Science, 08028, W. C. Woods, Jr., (609) 863-7348. Founded 1962, 20 members. Observatory with 6" scope.

**Glen Rock** — Montclair Telescope Club, Inc., 14 Iona Place, 07452, C. Thomas Massey, (201) 447-2581. Founded 1955, 30 members.

**High Bridge** — New Jersey Astronomical Association, P.O. Box 214, 08829, Ben Cavotta, (201) 638-8500. Founded 1965, 178 members. Observatory with 26" scope.

**Homdel** — STAR Astronomy Society, P.O. Box 547, 07743. Founded 1957, 46 members.

**Jamesburg** — Concordia Astronomy Club, P.O. Box 22, 08831-0022, Arnold Epstein, (609) 395-0755, 120 members.

**Merchantville** — Willingboro Astronomical Society, P.O. Box 1457, 08109, Joy Crist, (609) 829-4345. Founded 1960, 36 members. Observatory with 14" reflector and 6" refractor.

**Princeton** — Amateur Astronomers Association of Princeton, P.O. Box 2017, 08540, Larry Smith, (201) 874-3552. Founded 1973, 90 members. Observatory with 12.5" Newtonian and 6" refractor.

**Toms River** — Astronomical Society of the Toms River Area (ASTRA), c/o Novins Planetarium, Ocean County College, 08754-2001, R. Erik Zimmerman, (201) 255-0343. Founded in 1977, 70 members.

### NEW YORK

**Bay Shore** — Astronomical Society of Long Island, 1011 Howells Road, 11706, Jo-Ann Tompkins, (516) 586-1760. Founded 1960, 100 members.

**Buffalo** — Buffalo Astronomical Association, Inc., Buffalo Museum of Science, Humboldt Parkway, 14211, Doris Koestler, (716) 683-2970. Founded 1937, 110 members.

**Corning** — Elmira-Corning Astronomical Society, 17 West Hazel Street, 14830, Marilyn L. O'Connell, (607) 962-5435. Founded 1960, 60 members.

**Frewsburg** — Marshal Martz Memorial Astronomical Association, 176 Robin Hill Road, 14738, Gary Nelson, (716) 483-1955. Founded 1979, 75 members. Observatory with 30" Newtonian. Monthly star parties.

**Lindenhurst** — Amateur Observers' Society of New York, 707 South 9th Street, 11757, Eric Barnes, (516) 957-3713. Founded 1965, 52 members.

**Lockport** — Lockport Astronomy Association, 7053 Northview Drive, 14094, Richard Lahrs, (716) 433-4706. Founded 1966, 25 members. Observatory with 12" telescope with public observing every Wednesday night.

**Mattydale** — Syracuse Astronomical Society, Inc., 150 Hinsdale Road, 13211, Frank Rioux, (315) 455-8477. 110 members.

**New York** — Amateur Astronomers Association of New York, Inc., 1010 Park Avenue, 10028, John Pazmino, (212) 535-2922. Founded 1927, 550 members. Observatory with 17.5" Dobsonian.

**Pearl River** — Rockland Astronomy Club, 110 Pascack Avenue, 10965, Allan Green, (914) 735-7303. Founded in 1970, 250 members.

**Rochester** — RIT Astronomy Club, Rochester Institute of Technology, Dept. of Physics - 08, 14623. Founded 1989, 30 members.

**Rochester** — Rochester Academy of Science Astronomy Club, 105 Wyandover Road, 14616, David Smith, (716) 621-7593.

**Saranac Lake** — Tri-Lakes Astronomical Society, P.O. Box 806, 12985, Daniel Ferguson, (518) 891-0339.

**Schenectady** — Albany Area Amateur Astronomers, 1529 Valencia Road, 12309, Bob Mulford, (518) 374-8744. Founded 1949, 50 members. Observatory with 18" Dobsonian.

**Southold** — Custer Institute, P.O. Box 1204, Main Bayview Road, 11971, Barbara Lebkvecher, (516) 722-3850. Founded 1920, 175 members. Observatory with 5" Clark refractor.

**Staten Island** — Astronomical Society of New York City, 153 Arlo Road, 10301, T. W. Hamilton, (718) 727-1967.

**Vestal** — Kopernik Astronomical Society, Roberson-Kopernik Observatory, Underwood Road, 13850, Jay Sarton, (607) 772-0660. Founded 1973, 120 members. Observatory with 14" scope. Public nights on Fridays, July 6-Aug. 10.

**Watertown** — Northern New York Astronomical Society, P.O. Box 106, 13601, Pete Beaumont, (315) 788-2472.

### PENNSYLVANIA

**Allentown** — Lehigh Valley Amateur Astronomical Society, 620 East Rock Road, 18103, George Maurer, (215) 967-1991. Operates 21' dome planetarium and observatory with 6" refractor and 12.5" Cassegrain.

**Cabot** — Kiski Astronomers, R.D. 1, P.O. Box 349, 16023, John Labrecque, (412) 352-3907. Founded 1968, 35 members.

**Glenshaw** — Amateur Astronomers Association of Pittsburgh, P.O. Box 314, 15116, John Holtz, (412) 224-2510. Founded 1929, 230 members. Observatory with 12.5" Newtonian. Monthly public star parties at Wagman Observatory.

**Kane** — Sir Isaac Newton Astronomical Society, Box 591, 16735, William Bloom, (814) 837-6137.

**Kimberton** — Delaware Valley Amateur Astronomers, P.O. Box 662, 19442-0662, Marilyn Michalski, (215) 933-0497. Founded 1976, 170 members.

**Lewisberry** — Astronomical Society of Harrisburg, P.O. Box 356, 17339. Founded 1955, 170 members.

**New Brighton** — Beaver Valley Astronomy Club, 818-6th Avenue, 15066, Charles A. Sabella, (412) 843-8931. Founded 1978, 20 members.

**Philadelphia** — Rittenhouse Astronomical Society, P.O. Box 12531, 19131, Milt Friedman, (215) 886-3466.

**Reading** — Berks County Amateur Astronomical Society, Reading School District Planetarium, 1211 Parkside Drive South, 19611. Founded 1973, 40 members.

**Scranton** — Lackawana Astronomical Society, 1047 Mohawk Street, 18508, John D. Sabia, (717) 586-0789.

### RHODE ISLAND

**Greenville** — Skyscrapers, Inc., P.O. Box 814, 02828, Bob Napier, (401) 934-0980.

### VERMONT

**Williston** — Vermont Astronomical Society, P.O. Box 782, 05495, Frank Pakulski, (802) 985-3269. Founded 1964, 50 members. Observatory with 9" Clark refractor.

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16507, (814) 453-5811. Open Tues.-Sun.

**Harrisburg** — State Museum of Pennsylvania Planetarium, 3rd and North Streets, Box 1026, 17108-1026, (717) 783-9914. Open Tues.-Sun.

**Lancaster** — North Museum Planetarium, Franklin & Marshall College, 17604, (717) 291-3941. Exhibits, observatory (11" refractor and 16" reflector), planetarium shows (40' dome). Open Wed.-Sun., daytime only.

**Philadelphia** — Franklin Institute/Fels Planetarium, 20th and the Parkway, 19103, (215) 448-1293. Exhibits, space artifacts, observatory. Open daily.

**Philadelphia** — University of Pennsylvania Observatory, Astronomy Dept., David Rittenhouse Laboratory, 33rd and Walnut Street, 19104, (215) 898-8176. Open Mon. and Thurs. evenings only.

**Pittsburgh** — Allegheny Observatory, 159 Riverview Avenue, 15214, (412) 321-2400.

**Pittsburgh** — Buhl Science Center, Allegheny Square, 15212, (412) 321-4302. Exhibits, planetarium, laser shows, observatory. Open daily.

**Reading** — Reading School District Planetarium, 1211 Parkside Drive South, 19611, (215) 371-5854. 40' dome theater. Open Mon.-Fri. afternoons only. Closed August.

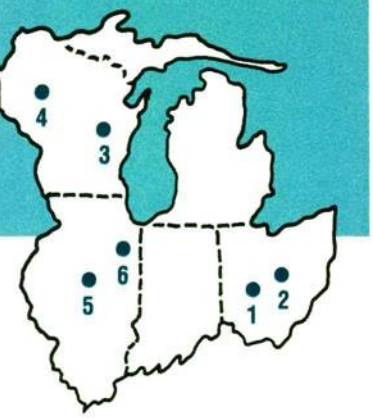
### RHODE ISLAND

**Charlestown** — Frosty Drew Observatory, Ninigret Park, P.O. Box 160, 02813, (401) 364-9508. 7" Christen Starfire refractor. Open Fri. evenings only.

**Providence** — Cormack Planetarium, Museum of Natural History, Roger Williams Park, 02905, (401) 785-9450. 26' dome theater, exhibits. Open Sat. & Sun. only.

**Providence** — Ladd Observatory, 210 Doyle Avenue, 02912, (401) 521-5680. 12" telescope. Public observing Wednesday evenings.

# Great Lakes



**1** **June 8-9**
20th Annual Apollo Rendezvous and Telescope Fair, sponsored by the Miami Valley Astronomical Society and the Dayton Museum of Natural History. Contact: Ian Dumbauld, 5932 Culzean Drive #706, Dayton, OH 45426.

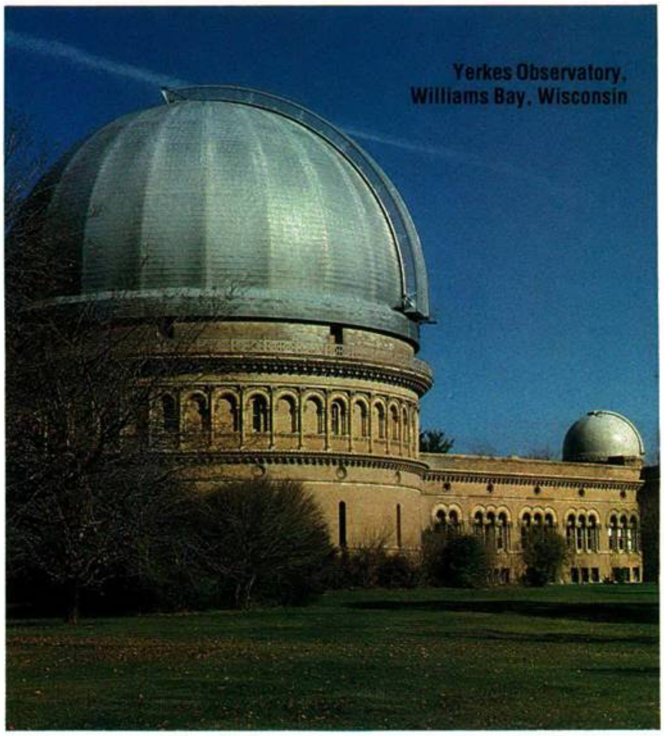
**2** **June 15**
Telescope Fair, Highbanks Metro Park, Columbus, OH, 7 to 11 p.m. Contact: Columbus Astronomical Society, c/o Tom Burns, 5280 Cape Cod Lane, Columbus, OH 43235.

**3** **June 22-24**
Third Annual Wisconsin Observers' Weekend, Hartman Creek State Park, Waupaca, WI. Sponsored by NEWSTAR, the Northeast Wisconsin Stargazers. Contact: Don Wyman, 1815 Kienast Avenue, Oshkosh, WI 54901, (414) 233-3083.

**4** **August 17-19**
Northwoods Starfest, Eau Claire Youth Camp, Beaver Creek Reserve, WI. Facilities include the new Hobbs Observatory Center. Sponsored by the Chippewa Falls Astronomical Society. Contact: Kevin Litten, 921 W. Willow, Chippewa Falls, WI 54729, (715) 726-2382.

**5** **August 24-26**
Fourth Annual Astronomy Rendezvous and Conference, Normal, IL. Contact: Twin City Amateur Astronomers, P.O. Box 755, Normal, IL 61761, Carl Wenning, (309) 454-4164.

**6** **September 14-16**
Astrofest '90, Kankakee River State Park, Kankakee, IL. A major star party and telescope-making competition hosted by the Chicago Astronomical Society. Contact: Astrofest, P.O. Box 596, Tinley Park, IL 60477.


Yerkes Observatory, Williams Bay, Wisconsin

## PLACES

### ILLINOIS

**Champaign** — William M. Staerkel Planetarium, Parkland College, 2400 West Bradley Avenue, 61821, (217) 351-2568. 50' dome theater, Cinema 360. Open Fri. & Sat. only.

**Chicago** — Adler Planetarium, 1300 South Lake Shore Drive, 60605, (312) 322-0304. 68' dome theater, exhibits, observatory (20" scope with CCD). Open daily in summer.

**Chicago** — Museum of Science & Industry and Crown Space Center, 57th Street and Lake Shore Drive, 60637, (312) 684-1414. Exhibits, OMNIMAX® theater. Open daily.

**Evanston** — Dearborn Observatory, Northwestern University, 2131 Sheridan Road, 60201, (708) 256-6639. 18" telescope. Public observing Friday evenings only by reservation.

**Normal** — Physics Dept. Planetarium, Illinois State University, 61761-6901, (309) 438-2496. 30' dome theater. Open Mon. & Wed. evenings only.

**Peoria** — Lakeview Museum/Planetarium, 1125 West Lake Avenue, 61614, (309) 686-7000. 33' dome theater, exhibits. Open Tues.-Sun.

**River Grove** — Cernan Earth & Space Center, Triton College, 2000 Fifth Avenue, 60171, (312) 456-5815. Exhibits, public observing, planetarium shows (44' dome), laser shows, Cinema 360. Open daily in summer.

**Rockford** — Discovery Center Museum, 711 North Main Street, 61103-6903, (815) 963-6769.

**Rockford** — The Time Museum, 7801 East State Street, 61108, (815) 398-6000. Extensive exhibits of historic timekeeping pieces, tours, films. Open Tues.-Sun. daytime only.

**Urbana** — University of Illinois Observatory, 349 Astronomy Building, 1011 N. Springfield Avenue, 61801, (217) 338-3090. 12" refractor. Public nights July 6 and Sept. 7.

### INDIANA

**Evansville** — Koch Science Center & Planetarium, 411 SE Riverside Drive, 47713, (812) 425-2406. 30' dome theater, exhibits. Open Tues.-Sun.

**Indianapolis** — Children's Museum of Indianapolis/Spacequest Planetarium, 3000 North Meridian Street, 46208, (317) 924-5431. 40' dome theater with Digistar projector, exhibits. Open daily in summer.

**Marshall** — Nature Center Planetarium, Turkey Run State Park, RR 1, Box 164, 47859, (317) 597-2654. 16' dome theater. Open daily in summer.

**Muncie** — Ball State University Planetarium, Dept. of Physics and Astronomy, 47306, (317) 285-8860. Open Mon.-Fri.

**Terre Haute** — Indiana State University Observatory, Dept. of Geology and Geography, Indiana State University, 47809, (812) 237-2271. Open Tues. & Fri. evenings.

### MICHIGAN

**Alpena** — Jesse Besser Museum and Planetarium, 491 Johnson Street, 49707, (517) 356-2202. 33' dome theater, exhibits. Open daily in summer, daytime only.

**Battle Creek** — Kingman Museum of Natural History, West Michigan Avenue at 20th Street, 49017, (616) 965-5117. Exhibits, public observing, planetarium shows. Open daily.

**Bloomfield Hills** — Cranbrook Institute of Science, 500 Lone Pine Road, 48013, (313) 645-3200. Exhibits, planetarium shows, laser shows, observatory. Open daily.

**Detroit** — Children's Museum/Detroit Public Schools, 67 East Kirby, 48202, (313) 494-1210. Exhibits, planetarium shows. Open daily in summer.

**Detroit** — Detroit Science Center, 5020 John R Street, 48202, (313) 577-8430. Exhibits, public observing, planetarium shows, laser shows, OMNIMAX® theater. Open Tues.-Sun.

**East Lansing** — Abrams Planetarium, Michigan State University, 48824, (517) 355-4676. 50' dome theater, exhibits, public observing. Open daily in summer.

**Flint** — Robert T. Longway Planetarium, 1310 East Kearsley Street, 48503, (313) 762-1181. 60' dome theater, laser shows, exhibits, public observing. Open daily in summer.

**Grand Rapids** — Roger B. Chaffee Planetarium, Grand Rapids Public Museum, 54 Jefferson SE, 49503, (616) 456-3200. 30' dome theater, laser shows, exhibits, public observing. Open daily in summer.

**Kalamazoo** — Hans Baldauf Planetarium, Kalamazoo Public Museum, 315 South Rose Street, 49007, (616) 345-7092. 30' dome theater, exhibits. Open daily in summer.

**Lansing** — Impression Five Science Museum, 200 Museum Drive, 48933, (517) 485-8116. Exhibits, public observing. Open daily.

**Marquette** — Shiras Planetarium, 1203 West Fair Avenue, 49855, (906) 225-4250. 30' dome theater. Open Monday evenings only, 7:30 p.m.

**Mount Pleasant** — Brooks Observatory, Central Michigan University, 48859, (517) 774-3321. 14" telescope. Open one Thursday evening per month.

**Muskegon** — Carr-Fles Planetarium, Muskegon Community College, 221 S. Quarterline Road, 49442, (616) 777-0289. 24' dome theater. Open Mon.-Fri. days only and Tues. evening.

### OHIO

**Canton** — Hoover-Price Planetarium, McKinley Museum, 800 McKinley Monument Drive, P.O. Box 20070, 44701, (216) 455-7043. 25' dome theater, exhibits. Museum open daily in summer, planetarium shows Mon.-Fri. only.

**Cincinnati** — Cincinnati Museum of Natural History and Planetarium, 1720 Gilbert Avenue, 45202, (513) 621-3889. Open Tues.-Sun.

**Cincinnati** — Cincinnati Observatory, 3489 Observatory Place, 45208, (513) 321-5186. 11" and 16" refractors. Open by reservation only.

**Cleveland** — Cleveland Museum of Natural History, Wade Oval, University Circle, 44106, (216) 231-4600. Mueller Planetarium (30' dome), observatory (10.5" refractor), exhibits. Open daily.

**Cleveland** — NASA Lewis Research

**Cleveland** — NASA Lewis Research Center, 21000 Brookpark Road, MS 8-1, 44135, (216) 433-2001. Visitor center, space artifacts, tours. Open daily.

**Cleveland** — Warner & Swasey Observatory, Case Western Reserve University, 44106, (216) 368-3728.

**Columbus** — Center of Science and Industry, 280 East Broad Street, 43215, (614) 228-2674. Exhibits, Batelle Planetarium theater (30' dome). Open daily, daytime only.

**Dayton** — Dayton Museum of Natural History, 2629 Ridge Avenue, 45414, (513) 275-7431. Exhibits, planetarium shows, observatory. Open daily.

**Delaware** — Perkins Observatory, P.O. Box 449, 43015, (614) 363-1257. Open Mon.-Fri. afternoons only. Public viewing one night per month.

**Granville** — Swasey Observatory, Denison University, 43023, (614) 587-6477. 9" telescope. Tours Mon.-Fri. mornings. Call for evening schedule.

**Sylvania** — Copernicus Planetarium, Lourdes College, 6832 Convent Boulevard, 43560, (419) 885-3211. 24' dome theater, exhibits. Open Mon.-Sat.

**Westerville** — North American Astrophysical Observatory, Otterbein College, 43081, (614) 898-1516. 320' by 71' radio telescope. Open by reservation only.

**Wilmot** — Wilderness Center Planetarium, 9877 Alabama Avenue, SW, P.O. Box 202, 44689, (216) 359-5235. 12' dome theater, public observing. Center open Tues.-Sun., daytime only.

### WISCONSIN

**Eau Claire** — L.E. Phillips Planetarium, University of Wisconsin, 54701, (715) 836-2408. 24' dome theater. Open Wednesday evenings only.

**Fall Creek** — Beaver Creek Reserve Observatory, Box 94, 54742, (715) 877-2212. Open first Sunday of each month.

**Madison** — Washburn Observatory, University of Wisconsin-Madison, 1401 Observatory Drive, 53706, (608) 262-8544. 15" refractor. Open clear Wednesday evenings June 20-Aug. 15. Call 262-WASH for update.

**Menasha** — University of Wisconsin-Fox Valley Planetarium, 1478 Midway Road, 54952, (414) 832-2616. Open Sunday evenings, 7 p.m.

**Stevens Point** — University of Wisconsin-Stevens Point Planetarium, Science Building, 740 Reserve Street, 54481, (715) 346-2208. 25' dome theater. Open Wednesday evenings only.

**Williams Bay** — Yerkes Observatory, University of Chicago, Geneva Street, P.O. Box 258, 53191, (414) 245-5555. Largest refractor (40") in the world. Open Sat. afternoons only in summer.

## CLUBS

### ILLINOIS

**Batavia** — Fox Valley Astronomical Society, P.O. Box 508, 60510, Ray Whaley, (708) 897-5218. Founded 1944, 45 members. Observatory with 16" Newtonian. Public star parties June 15, July 27, and August 17.

**Chicago** — Chicago Astronomical Society, P.O. Box 48540, 60648.

**Glenview** — Skokie Valley Astronomers, 910 Glenwood Lane, 60025, Gretchen George, (312) 998-1627. Founded 1984, 25 members. Meetings at Ryerson Nature Center. Also the contact for the Space Science Explorers Club for youths.

**Libertyville** — Lake County Astronomical Society, 603 Dawes Street, 60048, Jack Kramer, (708) 362-0959. Founded 1982, 65 members.

**Lisle** — Illinois Benedictine College Astronomical Society, 5700 College Road, 60532-2099, Robert S. Buday, (312) 969-6550. Founded 1965, 15 members. Observatory with 16.5" Springfield telescope.

**Normal** — Twin City Astronomers, Inc., c/o Illinois State University Planetarium, P.O. Box 755, 61761, Carl J. Wenning, (309) 454-4164. Founded 1960, 75 members.

**Peoria** — Peoria Astronomical Society, Inc., 1125 West Lake Avenue, 61614, Eric Clifton, (309) 686-2864.

**Quincy** — Quincy Astronomical Society, #22 Summer Creek Drive, RR 9, 62301-9808, Brad Haubrich, (217) 222-8832. Founded 1985, 30 members. Observatory with 16" scope.

**Rock Island** — Popular Astronomy Club, Inc., c/o John Deere Planetarium, Augustana College, 61201, Paul Castle, (309) 786-6119.

**Rockford** — Rockford Amateur Astronomers, Inc., 6804 Alvina Road, 61101, Barry or Carol Bearman, (815) 962-6540. Founded 1958, 75 members. Public viewing 2nd and 4th Saturdays at Lockwood Park Observatory (10" Christen refractor).

**St. Charles** — Argonne Astronomy Club, 6N106 White Oak Lane, 60175, H. F. DaBoll, (312) 584-1162.

**Schaumburg** — Northwest Suburban Astronomers, 1417 Harvard Lane, 60193, Detlef Schmidt. Founded 1971, 120 members.

**Springfield** — Springfield Astronomy Society, 2224 S. 13th Street, 62703, Don Walker.

**Sugar Grove** — Fox Valley Sky Watchers, Wauhonsee Community College, Route 147, 60118, Mike Anderer, (312) 377-6141.

### INDIANA

**Evansville** — Evansville Astronomical Society, P.O. Box 3474, 47733, Jeff Bunner.

**Fort Wayne** — Fort Wayne Astronomical Society, P.O. Box 6004, 46896, Greg O'Neill.

**Griffith** — Calumet Astronomical Society, P.O. Box 851, 46319, Stephen Miller, (219) 845-9174. Founded 1975, 35 members.

**Mooresville** — Indiana Astronomical Society, 2 Wilson Drive, 46158, J. Philip May, (317) 831-3009. Founded 1933, 150 members. Observatory with 36" Cassegrain.

**South Bend** — Michiana Astronomical Society, P.O. Box 262, 46624, Dan Smith, (219) 282-1086. Founded 1973, 30 members.

**Warsaw** — Warsaw Astronomical Society, RR 8, Box 236, 46580, Jim Tague, (219) 269-1856.

**West Lafayette** — Wabash Valley Astronomical Society, 2367 Yeager Road #102, 47906, William Annis, (317) 463-3741. Founded 1965, 25 members. Observatory with 14" Celestron.

### MICHIGAN

**Bridgeport** — Sunset Astronomical Society, 3622 Towerline, 48722, Timothy Ross, (517) 777-2824. Founded 1974, 30 members. Observatory with Celestron 16.

**Brighton** — Friends United Through Astronomy, 8191 Woodland Shore, Lot #12, 48116, Gary Anderson, (313) 227-9347. Founded 1982.

**Detroit** — Detroit Astronomical Society, 14298 Lauder Avenue, 48219. Founded 1932, 60 members. Skywatchers Hotline (313) 837-0130.

**East Detroit** — Warren Astronomical Society, P.O. Box 474, 48021. Founded 1961, 90 members. Observatory with 12.5" scope. Summer Solstice Star Party June 23.

**East Lansing** — Capital Area Astronomy Club, c/o Abrams Planetarium, Michigan State University, 48824, David Batch, (517) 355-4676. 50 members.

**Hillsdale** — Astronomical Society of Hillsdale, 3260 North Dunes Road, 49242, Pat Calligan, (517) 439-1295. Founded 1985, 20 members.

**Kalamazoo** — Kalamazoo Astronomical Society, Kalamazoo Public Museum, 315 South Rose Street, 49007, Eric Schreur, (616) 345-7092. Founded 1936, 20 members.

**Lowell** — Grand Rapids Amateur Astronomical Association, c/o James C. Veen Observatory, 3308 Kissing Rock Road SE, 49331, Evelyn Marron, (616) 897-7065. Observatory with 17" Newtonian and 6" refractor. Open 2nd Saturday and last Friday of each month.

**Marquette** — Marquette Astronomical Society, c/o Shiras Planetarium, 1203 West Fair Avenue, 49885, Brian Halbrook, (906) 228-6351. Founded 1974, 15 members. Observatory with 10" Newtonian.

**Muskegon** — Muskegon Astronomical Society, P.O. Box 363, 49443-0363, Dale Johnson, (616) 798-7680. Founded 1975, 35 members. Observatory with 12.5" reflector.

**Petersburg** — Toledo Astronomical Association, 8534 Covert Road, 49270, Courtney J. Earhart, (313) 856-6204. Founded 1975, 50 members. Observatory with 25" Newtonian.

**Plymouth** — Astronomical Society of Michigan, 11422 Waverly, 48170, Michael Best, (313) 459-BEST. Founded 1985, 187 members.

**Sturgis** — Sturgis Astronomy Group, 302 Virginia, 49091, Philip Thrasher, (616) 651-8176. Founded 1957, 6 members.

**Traverse City** — Grand Traverse Astronomical Society, 5999 Secor, 49684, Jerry Dobek, (616) 922-1260. Founded 1982, 32 members. Observatory with 14" SCT.

### OHIO

**Akron** — Astronomy Club of Akron, 1630 Thornapple Avenue, 44301, Mark Kochheiser, (216) 724-7761. Founded 1949, 120 members. Observatory with 12.5" scope.

**Chagrin Falls** — Chagrin Valley Astronomical Society, P.O. Box 11, 44022, Don Himes, (216) 247-5114. Founded 1962, 20 members. Hosting Ohio Amateur Astronomers' Association Convention, July 21.

**Columbus** — Columbus Astronomical Society, 5280 Cape Cod Lane, 43235, Tom Burns, (614) 459-7742. Founded 1948, 180 members.

**Dayton** — Miami Valley Astronomical Society, 2629 Ridge Avenue, 45414, Wade E. Allen, (513) 275-7431.

**Fostoria** — Sandusky Valley Amateur Astronomy Club, Seneca Wire and Manufacturing, 319 South Vine Street, 44830, Bill Davis, (419) 435-5953.

**Lorain** — Black River Astronomical Society, 1631 Maple Drive, 44052, Michael Harkey, (216) 288-8556. Founded 1948, 50 members. Observatory with 13.1" reflector. Annual astronomy convention Sept. 15.

**Mansfield** — Richland Astronomical Society, P.O. Box 1118, 44901, Keith Moore, (419) 468-3542. Founded 1960, 38 members. Observatory with 31" Newtonian. Open house first Sat. each month.

**Parma** — Cuyahoga Astronomical Association, P.O. Box 29089, 44129, Dawn Jenkins, (216) 521-5115. Founded 1959, 71 members. Hosting Annual Convention and Star Party, June 23.

**Wilmot** — Wilderness Center Astronomy Club, P.O. Box 202, 9877 Alabama Ave. SW, 44689-0202, Dave Gill, (216) 359-5235. Founded 1983, 50 members.

### WISCONSIN

**Chippewa Falls** — Chippewa Valley Astronomy Society, P.O. Box 21, 54729, Peter Peloquin, (715) 723-7862. Founded 1982, 34 members. Observatory with 24" reflector.

**Franklin** — Wehr Astronomical Society, 9701 West College Avenue, 53132, Karen Kerans, (414) 425-8550. Founded 1981, 75 members. Monthly star parties at the Bong State Recreation Area.

**Grafton** — Northern Cross Science Foundation, 1327-11th Avenue, 53024, William Fisher, (414) 377-0468. Founded 1976, 40 members. Observatory with 17.5" scope. Open house monthly.

**Green Bay** — Neville Museum Astronomical Society, 210 Museum Place, 54303, Donn Quigley, (414) 436-3767. Founded 1966, 50 members. Observatory with 30" Cassegrain. Public star party July 27, Bay Beach Wildlife Sanctuary.

**La Crosse** — La Crosse Area Astronomical Society, P.O. Box 2041, 54602-2041, Robert Allen, (608) 785-8669.

**Madison** — Madison Astronomical Society, Inc., 205 Cameo Lane, 53714-2514, David D. Weier, (608) 241-1444. Founded 1930, 75 members. Observatory with 17.5" scope.

**Oshkosh** — NEWSTAR-Northeast Wisconsin Stargazers, 1815 Kienast Avenue, 54901, Don Wyman, (414) 233-3083. Founded 1986, 45 members.

**Racine** — Racine Astronomical Society, P.O. Box 085694, 53408, Don Sorenson, (414) 878-2774. Founded 1956, 56 members. Observatory with 16" telescope. Public nights every Thursday.

**Waukesha** — Milwaukee Astronomical Society, W248 S7040 Sugar Maple Drive, 53186. Founded 1932, 375 members. Observatory with 25.7" telescope. Monthly public viewing.

# Southeast

**1** **May 19-20**
16th Annual Virginia Association of Astronomical Societies Convention, Portsmouth campus, Tidewater Community College. Contact: Tidewater Community College Astronomical Society, TCC Physics Dept., State Route 135, Portsmouth, VA 23703, David Bianco, (804) 484-9656.

**2** **June 2**
Public Star Party, Carolina Beach State Park, NC. Contact: Cape Fear Astronomical Society, 110 Linville Drive, Castle Hayne, NC 28429, Paul Petty, (919) 675-2952.

**3** **September 22 and October 20**
Sixth Annual Blue Ridge Parkway Regional Stargaze, Julian Price Park, 4.5 miles south of Blowing Rock, NC. Camping, hiking, and dark skies. Contact: Greg Kirby, 12 East Street, Granite Falls, NC 28630, (704) 396-7656.

## PLACES

### ALABAMA

**Birmingham** — Robert R. Meyer Planetarium, Birmingham Southern College, 35254, (205) 226-4770. Open weekdays and Sundays.

**Florence** — University of North Alabama Planetarium/Observatory, 35632, (205) 760-4284.

**Huntsville** — Marshall Space Flight Center, 35812, (205) 544-0034.

### DISTRICT OF COLUMBIA

**Washington D.C.** — Albert Einstein Planetarium, National Air & Space Museum, Smithsonian Institution, 6th Street and Independence Avenue, SW, 20560, (202) 357-7000. Space artifacts, planetarium shows, IMAX® theater. Open daily.

**Washington D.C.** — Rock Creek Nature Center, 5200 Glover Road, NW, 20015, (202) 426-6829. Exhibits, planetarium shows. Open daily.

**Washington D.C.** — U.S. Naval Observatory, 34th and Massachusetts Avenue NW, 20392, (202) 653-1543. 26" and 12" Clark refractors. Open Monday evenings only, except federal holidays.

### GEORGIA

**Atlanta** — Fernbank Science Center, 156 Heaton Park Drive NE, 30307, (404) 378-4311. Jim Cherry Memorial Planetarium (70' dome), exhibits, observatory (36" telescope). Open daily in summer.

**Columbus** — Patterson Planetarium, 2900 Woodruff Farm Road, 31901, (404) 568-1730. 40' dome theater. Open Mon.-Fri. by reservation. Observing 9 p.m. Tues. at Pine Mtn.

**Decatur** — Agnes Scott College Planetarium/Bradley Observatory, 30030, (404) 371-6265. 13' dome theater, 14" telescope. Open one Friday per month.

**Macon** — Mark Smith Planetarium and Observatory, 4182 Forsyth Road, 31210, (912) 477-3232. Open daily.

**Savannah** — Savannah Science Museum, 4405 Paulsen Street, 31405, (912) 355-6705. Exhibits, planetarium (24' dome). Open Tues.-Sun.

**Young Harris** — Rollins Planetarium, Young Harris College, 30582, (404) 379-3990. Open Fridays.

### KENTUCKY

**Berea** — Weatherford Planetarium, Berea College, CPO 2326, 40404, (606) 986-9341. 30' dome theater, observatory (16" telescope). Open Sat. & Sun. afternoons. Observatory Tues. evenings only.

**Louisville** — Museum of History & Science, 727 West Main Street, 40402, (502) 561-6103, Exhibits, IMAX® theater. Open daily.

**Louisville** — Rauch Memorial Planetarium, University of Louisville, 40292, (502) 588-6665.

**Richmond** — Hummel Planetarium, Eastern Kentucky University, 40475, (606) 622-1547. 67' dome theater, large format 35/70mm films. Open daily in summer.

### MARYLAND

**Baltimore** — Maryland Science Center, Davis Planetarium, 601 Light Street, 21230, (301) 685-5225. Exhibits, planetarium shows (50' dome), IMAX® theater. Open daily.

**College Park** — University of Maryland Observatory, 1205 Space Sciences Building, 20742, (301) 454-3001. 20" telescope. Open 5th and 20th of each month at 9 p.m.

**Greenbelt** — NASA Goddard Space Flight Center, Code 224, 20771, (301) 982-5085.

**Hagerstown** — Washington County Planetarium and Space Science Center, 823 Commonwealth Avenue, 21740, (301) 791-4172. Exhibits, planetarium shows (30' dome). Open Tuesday evenings only.

### MISSISSIPPI

**Jackson**—Ronald E. McNair Space Theater, Russell Davis Planetarium, 201 East Pascagoula Street, 39201, (601) 960-1550. Exhibits, planetarium shows, laser shows. Open Tues.-Sun.

### NORTH CAROLINA

**Chapel Hill** — Morehead Planetarium, University of North Carolina-Chapel Hill, Morehead Building, CB 3480, UNC-CH, 27599, (919) 962-1236. Exhibits, laser shows, observatory. Open daily.

**Charlotte** — Science Museums of Charlotte, 301 North Tryon Street, 28202, (704) 337-2618. Planetarium shows (24' dome), exhibits. Open daily in summer, daytime only.

**Durham** — North Carolina Museum of Life & Science, 433 Murray Avenue, P.O. Box 15190, 27704, (919) 477-0431. Exhibits, space artifacts. Open daily in summer.

**Greensboro** — Edward Zane Planetarium, The Natural Science Center of Greensboro, 4301 Lawndale Drive, 27408, (919) 288-3769. 40' dome theater, exhibits, solar observatory. Open daily in summer.

**Hickory** — Catawba Science Center, 243 3rd Avenue NE, P.O. Box 2431, 28603, (701) 322-8169. Exhibits, Starlab planetarium. Open Tues.-Sun.

**Salisbury** — Margaret C. Woodson Planetarium, 1636 Parkview Circle, 28144, (704) 636-3462. Exhibits, observatory. Open Mon.-Fri. and by reservation on Sat. & Sun. evenings.

**Winston-Salem** — Nature Science Center/Hanes Planetarium, Museum Drive, 27105, (919) 767-6730. 20' dome theater, exhibits. Open daily.

### SOUTH CAROLINA

**Columbia** — Gibbes Planetarium, 1112 Bull Street, 29201, (803) 343-2207. 26' dome theater. Open Sat. & Sun.

**Columbia** — Melton Memorial Observatory, University of South Carolina, Dept. of Physics & Astronomy, 29208, (803) 777-6446. 16" reflector. Open clear Mondays, 9:30-11 p.m.

**Florence** — Francis Marion College Planetarium, 29501, (803) 661-1250. 33' dome theater, observatory (14" telescope). Open 2nd and 4th Sundays only.

**Greenville** — Roper Mountain Science Center & Daniel Observatory, 504 Roper Mountain Road, 29615, (803) 297-0232. Planetarium shows (50' dome and Digistar projector), 23" Clark refractor. Open second Saturday of the month.

**Orangeburg** — Stanback Museum and Planetarium, South Carolina State College, 29117, (803) 536-8711. Open Mon.-Fri.

**Rock Hill** — Settlemyre Planetarium, Museum of York County, 4621 Mt. Gallant Road, 29730, (803) 329-2121. 30' dome theater, exhibits. Open daily.

### TENNESSEE

**Kingsport** — Bays Mountain Planetarium and Nature Center, Route 4, 37660, (615) 229-9447. 40' dome theater, exhibits, laser shows, observatory (17.5" telescope). Open daily in summer.

**Knoxville** — East Tennessee Discovery Center/Akima Planetarium, P.O. Box 6204, 516 Beaman Street, 37914, (615) 637-1121. 30' dome theater, exhibits. Open daily in summer.

**Memphis** — Memphis Pink Palace Museum and Planetarium, 3050 Central Avenue, 38111, (901) 454-5609.

**Nashville** — A.J. Dyer Observatory, c/o Vanderbilt University, Box 1803 Station B, 37235, (615) 373-4897. 24" telescope. Public nights July 5 and Sept. 13. Observatory located at 1000 Oman Drive, Brentwood.

**Nashville** — Stevenson Center Observatory, Vanderbilt University, 37235, (615) 373-4897. 6" telescope. Public nights June 4, July 6, & Sept. 27.

**Nashville** — Sudekum Planetarium, Cumberland Science Museum, 800 Ridley Boulevard, 37211, (615) 259-6383. Exhibits, 40' dome theater, laser shows. Open daily in summer.

### VIRGINIA

**Arlington** — Arlington Planetarium, 1426 North Quincy St., 22207, (703) 358-6070. 30' dome theater, observatory (10" telescope). Open daily.

**Charlottesville** — Leander McCormick Observatory, University of Virginia, P.O. Box 3818, 22903, (804) 924-7494. 26" Clark refractor. Public observing 1st and 3rd Friday of each month through summer.

**Hampton** — NASA Langley Visitor Center, Mail Stop 480, 23665, (804) 865-2855. Exhibits, space artifacts, tours. Open daily.

**Harrisonburg** — John C. Wells Planetarium, James Madison University, 22801, (703) 568-6109. Open Mon. & Thurs. evenings.

**Newport News** — Virginia Living Museum Planetarium, 524 J. Clyde Morris Boulevard, 23601, (804) 595-1900. 30' dome planetarium, observatory (14" scope). Open daily in summer.

**Richmond** — Science Museum of Virginia, Universe Space Theater, 2500 West Broad Street, 23220, (804) 257-1657. Exhibits, planetarium shows with Digistar projector, OMNIMAX® films. Open daily.

**Roanoke** — Science Museum of Western Virginia/Hopkins Planetarium, One Market Square, 24011, (703) 342-5710. 40' dome theater, Cinema 360, exhibits, public observing. Open Tues.-Sun.

**Virginia Beach** — Virginia Beach City Public Schools Planetarium, 3080 South Lynnhaven Road, 23452, (804) 431-4067. 40' dome theater, exhibits, public observing. Open Tues. & Sun. evenings only.

**Wallops Island** — NASA Wallops Flight Facility, 23337, (804) 824-1344. Visitor center, exhibits, space artifacts. Tours by reservation. Open daily in summer, daytime only.

### WEST VIRGINIA

**Charleston** — Sunrise Children's Museum Planetarium, 746 Myrtle Road, 25314, (304) 344-8035. 24' dome theater, exhibits, public observing. Open Fri. & Sat. only.

**Green Bank** — National Radio Astronomy Observatory, P.O. Box 2, 24944, (304) 456-2011. Exhibits, tours. Open daily in summer.

**Wheeling** — Benedum Natural Science Center, Oglebay Park, 26003, (304) 242-3000. Exhibits, planetarium shows, laser shows, observatory. Open daily.

### ALABAMA

**Auburn** — Auburn Astronomical Society, 1963 Canary Street, 36830, Rhonala M. Jenkins.

**Birmingham** — Birmingham Astronomical Society, 1458 Al Seier Road, 35226, Mark Lancaster, (205) 853-0663. Founded 1977, 130 members. Observatory with 16" telescope. Public star party June 23.

**Huntsville** — Von Braun Astronomical Society, Box 1142, 35807. Founded 1965, 130 members. Observatory with 21" Cassegrain.

**Mobile** — Mobile Astronomical Society, P.O. Box 160972, 36616-1972, Leland Cox, (205) 633-9079. Founded 1983, 50 members. Observatory with 12.5" reflector.

**Rainbow City** — Southside Astronomy Club, 103 Eddie Circle, 35901, Julian Long, (205) 442-7169.

**Tuscumbia** — Muscle Shoals Astronomical Society, 302 NE Commons, 35674, Homer Russell, Jr., (205) 383-6717.

### GEORGIA

**Athens** — Athens Astronomical Association, 160 Plantation Drive, 30605, Maurice E. Snook, (404) 543-3753. Founded 1977, 20 members.

**Atlanta** — Astronomical Society of the Atlantic, c/o Center for High Angular Resolution Astronomy, Georgia State University, 30303, (404) 264-0451. Founded 1988, 150 members. Observatory with 30" telescope.

**Atlanta** — Atlanta Astronomy Club, 1002 Citadel Drive, 30324, Leonard Abbey, (404) 634-1222. Founded 1947, 150 members. Observatory with 20" telescope.

**Augusta** — Astronomy Club of Augusta, P.O. Box 6373, 30916, Jerry Barton, (404) 793-3420.

**Macon** — Middle Georgia Astronomical Society, c/o Museum of Arts and Sciences, 4182 Forsyth Road, 31210, Gary L. Kretsinger, (912) 956-2145.

**Savannah** — Oglethorpe Astronomical Association, 4405 Paulsen Street, 31405, Vickie Psillos, (912) 355-6705. Founded 1969, 17 members. Observatory with 16" reflector.

### KENTUCKY

**Golden Pond** — West Kentucky Amateur Astronomers, Land between the Lakes, 42211-9001, Jim Boren, (615) 232-7405. Founded 1980, 25 members. Observatory with 12.5" reflector.

**Louisville** — Louisville Astronomical Society, c/o Museum of History and Science, 727 West Main Street, 40402, Alan Goldstein, (502) 589-4584.

### MARYLAND

**Bel Air** — Hartford County Astronomical Society, P.O. Box 906, 21014, Gary McDaniel, (301) 838-1338.

**Bowie** — Bowie Astronomical Society, 12700 Bridle Place, 20715, Fred Espenak.

**Cumberland** — Cumberland Astronomy Club, 350 Bedford Street, 21502, G. Frank Simpson, (301) 722-7606. Founded 1964, 35 members.

**Glen Burnie** — Baltimore Astronomical Society, 305 Patsy Avenue, 21061, Jacki Zeun, (301) 766-6605.

**Greenbelt** — Goddard Astronomy Club, Goddard Space Flight Center, Code 440.8, 20771, George Gliba, (301) 345-4760. Founded 1961, 50 members. Observatory with 20" telescope.

**Hagerstown** — Tristate Astronomers, c/o Washington County Planetarium, 823 Commonwealth Avenue, 21740, Rodney L. Martin, (301) 791-4172. Founded 1985, 40 members. Observatory with 16" telescope.

**Westminster** — Westminster Astronomical Society, 3481 Salem Bottom Road, 21157, Curtis Roelle, (301) 848-6384. Founded 1984, 70 members.

### MISSISSIPPI

**Jackson** — Jackson Astronomical Association, 6207 Winthrop Circle, 39206, Walter Rebmann, Jr., (601) 982-2317. Founded 1973, 35 members. Observatory with 13" telescope.

### NORTH CAROLINA

**Albemarle** — Stanly County Astronomical Society, P.O. Box 1269, 28001, Herbert Hartley, (704) 982-3728. Founded 1985, 15 members. Monthly star parties at Morrow Mountain State Park.

**Asheville** — Starfax Association, P.O. Box 6084, 28816, Timothy Jordan. Founded 1981, 40 members.

Maryland Science Center IMAX Theater, Baltimore

**Castle Hayne** — Cape Fear Astronomy Club, 110 Linville Drive, 28429, Paul Petty, (919) 675-2952. Founded 1983, 50 members.

**Fayetteville** — Astronomy Club of Cumberland County, 2308 Colgate Drive, 28304, Allen Faircloth, (919) 485-8515. Founded 1981, 23 members.

**Gastonia** — Gaston Astronomy Club, P.O. Box 953, 28054, Larry Benefield, (704) 825-5341.

**Goldsboro** — Eastern Carolina Astronomy Club, 1607 Munroe Lane, 27534, Robert Krieger, (919) 778-3377. Founded 1989.

**Granite Falls** — Catawba Valley Astronomy Club, 12 East Street, 28630, Greg Kirby, (704) 396-7656. Founded 1976, 64 members.

**Greensboro** — Greensboro Astronomy Club, c/o Natural Science Center, 4301 Lawndale Drive, 27408, Wid Painter, (919) 454-4789. Founded 1947, 50 members. Monthly star parties at Hagan-Stone Park.

**Matthews** — Charlotte Amateur Astronomers Club, 245 Timber Lane, 28105, Gayle Riggsbee, (704) 846-3136. Founded 1954, 80 members. Observatory with 16" and 17.5" telescopes.

**Raleigh** — Raleigh Astronomy Club, P.O. Box 10643, 27605, (919) 832-NOVA. Founded 1977, 54 members.

**Salisbury** — Astronomical Society of Rowan County, c/o Margaret Woodson Planetarium, 1636 Parkview Circle, 28144, Ellen Trexler, (704) 636-3462.

**Stedman** — Astronomy Club of Cumberland County, P.O. Box 297, 28391, Johnny Horne, (919) 483-4467. Founded 1983, 22 members.

**Trinity** — Thomasville Area Astronomy Club, Route 3 Box 273, 27370, Arthur Oates, (919) 431-5062. Founded 1986, 30 members.

**Winston-Salem** — Forsyth Astronomical Society, 504 Gayron Drive, 27105, Stan Griffin, (919) 744-7141.

### SOUTH CAROLINA

**Aiken** — Aiken Astronomy Club, USC-Aiken, Building 106, 171 University Parkway, 29801, Richard M. Albert, (803) 663-3105.

**Columbia** — Midlands Astronomy Club, 545 Westover Road, 29210, Luke Rohlfing, (803) 772-5634. Founded 1965, 85 members.

**Hanahan** — Lowcountry Stargazers, 1313 Springhill Road, 29406, John Smith, (803) 797-0146. Founded 1983, 50 members. Observatory with 16" scope.

**Rock Hill** — Carolina Stargazers Astronomy Club, Museum of York County, 4621 Mt. Gallant Road, 29732, M. Leon Knott, (803) 329-2121. Founded 1986, 95 members.

### TENNESSEE

**Brentwood** — Barnard-Seyfert Astronomical Society, c/o A.J. Dyer Observatory, 1000 Oman Drive, 32027, A.M. Heiser, (615) 373-4897.

**Chattanooga** — Barnard Astronomical Society, P.O. Box 90042, 37412, F. Randolph Helms, (615) 622-4762.

**Kingsport** — Bays Mountain Amateur Astronomers, Route 4, 37660, (615) 229-9447. Founded 1980, 50 members. Observatory with 17.5" reflector and 8" refractor.

**Kingsport** — Bristol Astronomy Club, 824 Hidden Valley Road, 37663, Ken Childress, (615) 239-3638. Founded 1955, 28 members. Observatory with 12.5" reflector.

**Knoxville** — Orion Research Forum and Network, P.O. Box 50291, 37950, Bob Miles, (615) 588-3087. Founded 1974, 12 members.

**Knoxville** — Smoky Mountain Astronomical Society, P.O. Box 6204, 37914-0204, Rita Fairman, (615) 637-1121, 30 members.

**Manchester** — Middle Tennessee Astronomy Society, 1305 Sycamore Street, 37355, Donald W. Male, (615) 728-7321. 15 members.

**Memphis** — Memphis Astronomical Society, 1229 Pallwood Road, 38122, Richard Moore, (901) 682-2003. Founded 1956, 71 members. Observatory with 16" and 20" telescopes.

### VIRGINIA

**Bassett** — Piedmont Astronomy Club, P.O. Box 865, 24055, James I. Marshall.

**Blacksburg** — Astronomy Club of Virginia Tech, Virginia Polytechnic Institute, 24061, Dr. John Simonetti, (703) 231-8740. Founded 1972, 80 members. Observatory with Celestron 14.

**Catlett** — Fauquier Astronomical Society, Route 2, Box 680, 22019, Andrew Snowder.

**Chesapeake** — Back Bay Amateur Astronomers, 2808 Flag Road, 23323, Glendon L. Howell, (804) 485-4242. Founded 1978, 10 members.

**Fredericksburg** — Triangulum Astronomical Society, P.O. Box 7464, 22404, Al Ventura, Jr., (703) 775-2337. Founded 1983, 11 members.

**Hampton** — Langley Skywatchers, 221 Raleigh Avenue, 23661, Charles Evans.

**Harrisonburg** — Shenandoah Valley Astronomy Club, James Madison University, Dept. of Physics, 22801, Henry W. Leap, (703) 568-6109.

**Lynchburg** — Lynchburg Astronomy Club, 4648 Locksview Road, 24503, Allen Majewski, (804) 384-5616.

**Nathalie** — Halifax Skywatchers, P.O. Box 22, 24502, Joe Lightcap, (804) 349-3700.

**Portsmouth** — Astronomical Society of Tidewater, 2216 County Street, 23704. Founded 1973, 25 members. Observatory with 10" reflector.

**Portsmouth** — Tidewater Community College Astronomical Society, State Route 135, 23703, David Bianco, (804) 484-9656. Founded 1980, 45 members. Observatory with Celestron 14.

**Reston** — Nova Space Society, 11208 Chestnut Grove Square #5, 22090-5105, Gary Sanger, (703) 435-0019.

**Richmond** — Richmond Astronomical Society, 709 Timken Drive, 23239, Gary Sydnor, (804) 741-3689.

**Roanoke** — Roanoke Valley Astronomical Society, 3721 Colony Lane SW, 24018, Gary Close, (703) 989-3474.

**Springfield** — Northern Virginia Astronomy Club, 6121 Rivanna Drive, 22150, Al Schumann, (703) 971-3259. Founded 1982, 120 members. Hosts annual Northern Virginia Telescope Meet.

**Virginia Beach** — Tidewater Amateur Telescope Makers, 677 Charlecote Drive, 23464, Don Wright, (804) 424-9430. Founded 1977, 20 members.

# Florida and Puerto Rico

**1** **September 29**
Astronomy Day, Mariner Mall, Pensacola, FL, noon to 10 p.m. Observing, displays, slide and video shows. Contact: Escambia Amateur Astronomers' Association, 4100 Lillian Highway, Pensacola, FL 32506. (904) 456-0078.

*Note:* Most Florida star parties are held in winter.

## PLACES

**Bradenton** — Bishop Planetarium, 201 10th Street West, 34205, (813) 746-4132. Exhibits, planetarium shows (50' dome), laser shows, observatory (6" refractor). Open Tues.-Sun.

**Cocoa** — Astronaut Memorial Hall, 1519 Clearlake Road, 32926, (305) 631-7889. Exhibits, planetarium (40' dome), laser shows, observatory (24" telescope). Open Mon.-Sat.

**Davie** — Buehler Planetarium, Broward Community College, 3501 Southwest Davie Road, 33314, (305) 475-6681. 40' dome theater, laser shows, exhibits, observatory (10" telescope). Open Fri.-Sun. only.

**Daytona Beach** — Museum of Arts and Sciences Planetarium, 1040 Museum Boulevard, 32014, (904) 255-0285. Open Tues.-Sat.

**Fort Myers** — Nature Center and Planetarium, 3456 Ortiz at Colonial, P.O. Box 06023, 33906, (813) 275-3435. 44' dome theater, laser shows, Cinema 360, exhibits, public observing. Open Thurs.-Sun.

**Gainesville** — University of Florida Observatory, 32601, (904) 392-2058. 12.5" telescope. Open Friday evenings only.

**Jacksonville** — Alexander Brest Planetarium, Jacksonville Museum of Sciences and History, 1025 Gulf Life Road, 32207, (904) 396-7062. 60' dome theater, exhibits, public observing. Open daily in summer.

**Kennedy Space Center** — NASA Kennedy Space Center's Spaceport, 32899, (305) 452-2121. Exhibits, space artifacts, tours, IMAX® theater. Open daily.

**Melbourne** — Space Coast Science Center, 1510 Highland Avenue, P.O. Box 36-1816, 32936, (407) 259-5572. Open Tues.-Sat.

**Miami** — Miami Space Transit Planetarium, 3280 South Miami Avenue, 33129, (305) 854-4242. 65' dome theater, laser shows, exhibits, observatory (17.5" telescope). Open daily in summer. Cosmic Hotline (305) 854-2222.

**Orlando** — John Young Planetarium, Orlando Science Center, 810 East Rollins Street, 32803, (407) 896-7151. Exhibits, observatory (8" scope), planetarium (40' dome), laser shows. Open daily in summer.

**St. Augustine** — Fountain of Youth Planetarium, 155 Magnolia Avenue, 32084, (904) 829-6138. 30' dome theater. Open daily.

**St. Petersburg** — St. Petersburg Junior College Planetarium, P.O. Box 13489, 5th Avenue North at 69th Street, 33710, (813) 341-4320. 24' dome theater, observatory. Open Friday evenings only.

**West Palm Beach** — Aldrin Planetarium and Gibson Observatory, South Florida Science Museum, 4801 Dreher Trail North, 33405, (407) 832-1988. Open Tues.-Sun.

## CLUBS

**Bradenton** — Local Group of Deep-Sky Observers, 2311 23rd Avenue West, 34205, Vic and Lynne Menard, (813) 747-8334.

**Cocoa** — Brevard Astronomical Society, P.O. Box 1084, 32923, Tom Olsen, (407) 725-2451. Founded 1971, 30 members.

**Coral Gables** — Belen Astronomy Club, 3700 Anderson Road, 33134.

**Fort Myers** — Southwest Florida Astronomical Society, P.O. Box 6583, Miracle Mile Station, 33911-6583, Manuel J. Mon, (813) 936-5669. Founded 1980, 55 members.

**Fort Pierce** — Treasure Coast Astronomical Society, 131 Queen Catherina Court, 34949, Walter Swentzell, (407) 465-4454. Founded 1982, 32 members.

**Gainesville** — Alachua Astronomy Club, 3426 SW 75th Street, 32607, Charles Tarjan, (904) 377-7403.

**Jacksonville** — Northeast Florida Astronomy Society, P.O. Box 16574, 32245, Mike Martinez, (904) 642-1619. Founded 1972, 50 members. Observatory with 14.25" Newtonian-Cassegrain.

**Key Biscayne** — Southern Cross Astronomical Society, 690 Allendale Road, 33149, Barb Yager, (305) 361-2502. Founded 1922, 130 members. Observatory with 10" scope. Public nights on Saturdays, 8-10 p.m.

**Largo** — Tampa Area Astronomy Society, 9890 82nd Street N., 34647, John Novak, (813) 392-4699. Founded 1951, 45 members. Observatory with 20" reflector.

**Melbourne** — FIT Astronomy Society, c/o Florida Institute of Technology, Physics Dept., 32901, Susan Shufelt, (407) 768-8000. 40 members. Observatory with Celestron 14.

**Orlando** — Central Florida Astronomical Society, 810 East Rollins Street, 32803, Doug Moningtan, (407) 896-7151. Founded 1955, 114 members.

**Panama City** — Astronomy Club of Bay County, 425 East 19th Street #106, 32405, Dick Suiter, (904) 785-0706.

**Pensacola** — Escambia Amateur Astronomers' Association, 6235 Omie Circle, 32504-7625, Dr. J. Wayne Wooten, (904) 484-1152. Founded 1977, 200 members. Bimonthly sky interpretation programs at Ft. Pickens.

**St. Augustine** — Ancient City Astronomy Club, P.O. Box 546, 32085-0546, A.L. Ponjee, (904) 797-5794. Founded 1974, 30 members. Observatory with 12.5" scope.

**St. Petersburg** — St. Petersburg Astronomy Club, Inc., 594 59th Street South, 33707, Daniel W. Bricker, (813) 343-1594. Founded 1927, 140 members. Operates Hickory Hill Observatory. Annual Perseid meteor watch August 11.

**Tampa** — M.A.R.S. Astronomy Club, 2401 Bayshore Blvd. #1404, 33629, Emilio Toro, (813) 253-3490. Founded 1984, 50 members.

**Tampa** — Museum Astronomical Resource Society, c/o Museum of Science and Industry, 4801 East Fowler Ave, 33617, Bryan Smith.

**West Palm Beach** — Astronomical Society of the Palm Beaches, c/o South Florida Science Museum, 4801 Dreher Trail N., 33405, Gary M. Bogner, (407) 832-1988.

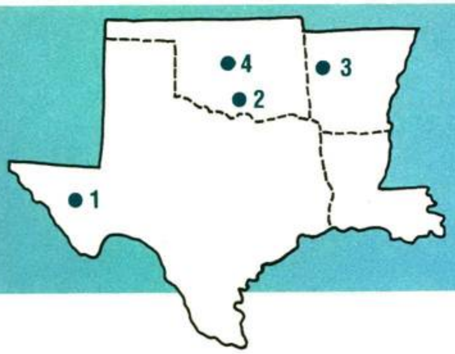
### PUERTO RICO

**Rio Piedras** — Sociedad de Astron. de Puerto Rico, Inc., Tegucigalpa 1025, Las Americas, 00921, Luis Maura, (809) 765-0889. Founded 1985, 70 members. Meetings conducted in Spanish.

**Arecibo** — Arecibo Radio Observatory, 00612, (809) 878-2612.

Kennedy Space Center, Florida

## South Central



**1** **May 20-28**
Texas Star Party, Prude Ranch, Fort Davis, TX. One of the big three star parties. Speakers include Brian Marsden and Walter Scott Houston. Contact: Registrar, Dept. A, P.O. Box 386, Wylie, TX 75098.

**2** **June 22-24**
Arbuckle Star Party, Arbuckle Observatory near Ardmore, OK. Contact: Arbuckle Astronomical Society, Route 1, Box 72, Tishomingo, OK 73460.

**3** **June 22-24**
Arkansas Star Party, 25 miles south of Fort Smith, AR. Sponsored by the Arkansas-Oklahoma Astronomical Society. Contact: Coleman Memorial Observatory, Route 1, Box 404, Hackett, AR 72937, (501) 474-4740.

**4** **September 18-22**
Okie-Tex Star Party. Contact: Oklahoma City Astronomy Club, P.O. Box 21221, Oklahoma City, OK 73156, Wayne Wyrick, (405) 424-5545.

## PLACES

### ARKANSAS

**Little Rock** — University of Arkansas-Little Rock Planetarium, 2801 South University Avenue, 72204, (501) 569-3259. 40' dome theater, laser shows, observatory (14.5" telescope). Open Fri. night and Sun. afternoon.

### LOUISIANA

**Baton Rouge** — Louisiana Arts and Science Center Planetarium, 502 North Boulevard, 70821, (504) 344-9465. Open Tues.-Sun.

**Lafayette** — Lafayette Natural History Museum and Planetarium, 637 Girard Park Drive, 70503, (318) 268-5544. Open daily.

**Luling** — St. Charles Parish Library and Planetarium, 91 Lakewood Drive, 70070, (504) 785-8471. 20' dome theater, observatory (8" telescope), exhibits. Open Mon.-Sat.

**New Orleans** — Louisiana Nature and Science Planetarium, Joe W. Brown Memorial Park, c/o P.O. Box 870610, 70187, (504) 246-STAR. Open Tues.-Sun.

### OKLAHOMA

**Oklahoma City** — Kirkpatrick Planetarium, OMNIPLEX Science Museum, 2100 N.E. 52, 73111, (405) 424-5545. 40' dome theater, exhibits, observatory (16" telescope). Open daily in summer, daytime only.

### TEXAS

**Amarillo** — Don Harrington Discovery Center, 1200 Streit Drive, 79106, (806) 355-9547. Exhibits, planetarium shows (40' dome) with Cinema 360. Open Tues.-Sun.

**Dallas** — Richland College Cosmic Theater & Planetarium, 12800 Abrams, 75243, (214) 238-6013. 40' dome theater, laser shows, public observing. Open Fri. & Sat. evenings and Sun. afternoons.

**Dallas** — The Science Place Planetarium, P.O. Box 11158, 75223, (214) 428-8351. 24' dome theater, exhibits. Open Tues.-Sun. daytime only.

**El Paso** — El Paso Planetarium, 6531 Boeing Drive, 79925, (915) 779-4317. 40' dome theater, exhibits, 25' laser video system, public observing. Exhibits open Mon.-Fri. Shows by reservation.

**Ft. Davis** — McDonald Observatory, W. L. Moody Visitor's Center, P.O. Box 1337, 79734, (915) 426-3240. 107", 82", 36" and 30" telescopes. Open daily in summer. Public observing Tues., Fri. & Sat. evenings. Viewing through 107" on one Wednesday per month near Full Moon.

**Ft. Worth** — Fort Worth Museum of Science & History, 1501 Montgomery Street, 76107, (817) 732-1631. Exhibits, planetarium shows (30' dome), laser shows, OMNIMAX® theater, observing. Open daily.

**Houston** — Burke Baker Planetarium, Houston Museum of Natural Science, One Hermann Circle Drive, 77030, (713) 526-4273.

**Houston** — Lyndon B. Johnson Space Center, 2101 NASA Road 1, 77058, (713) 483-4241. Open daily.

**Lubbock** — Moody Planetarium, Museum of Texas Technical University, 4th and Indiana Avenue, 79409, (806) 742-2432. 30' dome theater. Open Tues.-Sun. afternoons and Thurs. evenings.

**Nacogdoches** — Stephen Austin State University Planetarium, P.O. Box 13044, SFA Station, 75962, (409) 568-3001. 30' dome theater, observatory (1-meter telescope). Open Fri. evenings only, Sept. to May.

**Odessa** — Odessa Meteor Crater, c/o 1204 Texas Commerce Bank Building, 79761, (915) 332-1666. Exhibits

**San Angelo** — Angelo State University Planetarium, 76909, (915) 942-2136. 50' dome theater, exhibits, observing. Open daily in summer.

**San Antonio** — San Antonio College Planetarium, 1300 San Pedro Avenue, 78284, (512) 733-2910. Open Sunday evenings and by reservation.

**Tyler** — Hudnall Planetarium, Tyler Junior College, P.O. Box 9020, 75711, (214) 531-2312. 30' dome theater, exhibits, public observing. Open at 2 p.m. on the 1st and 3rd Sundays of the month during summer.

**Wichita Falls** — Wichita Falls Museum and Art Center Planetarium, #2 Eureka Circle, 76308, (817) 692-0923. 26' dome theater. Open Sat. & Sun.

## CLUBS

### ARKANSAS

**Arkadelphia** — Ark-La-Tex Skywatchers, P.O. Box 493, 71923, Rex McDaniel. Founded 1984, 26 members.

**Hackett** — Arkansas-Oklahoma Astronomical Society, c/o Coleman Memorial Observatory, P.O. Box 404, Route 1, 72937, (501) 474-4740. Founded 1985, 80 members.

**Little Rock** — Mid-South Astronomical Society, P.O. Box 5142, 72225, James Bruce McMath, (501) 376-3021. 30 members. Observatory with 12.5" telescope.

### LOUISIANA

**Baton Rouge** — Baton Rouge Astronomical Society, Inc., 17324 Gains Mill Avenue, 70817, Mark Stauffer, (504) 273-2320. Founded 1981, 40 members.

**Metairie** — Pontchartrain Astronomy Society, Inc., 6416 York Street, 70003, Ashby Spratley, (504) 885-2508. Founded 1959, 120 members. Observatory with 14" telescope.

**Shreveport** — Shreveport Astronomy Society, 1426 Alma Street, 71108, Cran Lucas, (318) 865-2433. 50 members.

### OKLAHOMA

**Bartlesville** — Bartlesville Astronomical Society, 225 SE Fenway Place, 74006, Ken Willcox, (918) 333-1966. Founded 1958, 23 members.

**Boise City** — Cimarron County Star Gazers, P.O. Box 278, 73933, Jim Rosebery, (405) 544-2222.

**Enid** — Northwest Oklahoma Astronomy Society, 1719 Pawnee, 73703, Dan Mathews, (405) 233-5707. Founded 1978, 50 members.

**Oklahoma City** — Oklahoma City Astronomy Club, P.O. Box 21221, 73156, Wayne Wyrick, (405) 424-5545. Founded 1958, 75 members. Observatory with 12.5" telescope.

**Sallisaw** — Sallisaw Amateur Telescope Club, 109 South Cedar, 74955, Bob Moody, (918) 775-3739.

**Tishomingo** — Arbuckle Astronomical Society, Route 1, Box 72, 73460, Carlton Rousey, (405) 371-2440. Founded 1987, 25 members. Observatory with 60" Cassegrain.

**Tulsa** — Astronomy Club of Tulsa, P.O. Box 740611, 74147-0611, Newell Pottorf, (918) 742-7577.

### TEXAS

**Abilene** — Abilene Astronomical Society, Inc., 1109 Highland Avenue, 79605, George Schroeder, (915) 677-5713.

**Amarillo** — Amarillo Astronomy Club, 4324 Summit Circle, 79109, Danny Zumbrun.

**Austin** — Austin Astronomical Society, P.O. Box 12831, 78711, Larry Kemp. 85 members. Observatory with 12" reflector.

**College Station** — Association of Amateur Astronomers, Texas A&M University, Dept. of Physics, 77843-4242, Roger Smith, (409) 845-4179.

**Corpus Christi** — Corpus Christi Astronomical Society, 3814 Marion Street, 78415, Gary Mayer, (512) 852-7643. Founded 1986, 10 members.

**Dallas** — Texas Astronomical Society, P.O. Box 25162, 75225, Sharon Cherry, (214) 358-6982. Founded 1946, 325 members.

**Ft. Worth** — Ft. Worth Astronomical Society, P.O. Box 161715, 76161-1715, Wade Weaver, (817) 731-0804. Founded 1949, 120 members. Observatory with 12" telescope.

**Ft. Worth** — General Dynamics Astronomy Club, 3400 Bryant-Irvin Road, 76109, Ronald W. Evans, (817) 763-6244.

**Ft. Worth** — Texas Observers, c/o Ft. Worth Museum of Science & History, 1501 Montgomery Street, 76107, Don Garland, (817) 732-1631.

**Houston** — Houston Astronomical Society, P.O. Box 20332, 77225-0332, John Chauvin, (713) 639-3452. Founded 1955, 410 members. Observatory with 14" telescope.

**Houston** — Students for the Exploration & Development of Space, University of Houston, 2700 Bay Area Boulevard, Box 198, 77058, Carlos Perez, (713) 486-9359. Founded 1987, 60 members.

**Lake Jackson** — Brazosport Astronomical Society, 500 College Drive, 77566, Steve Lamb, (409) 297-3984.

**Lubbock** — South Plains Astronomy Club, 1920 46th Street, 79412-2214, Wayne Lewis, (806) 763-6800. Founded 1960, 30 members.

**Odessa** — Permian Basin Astronomical Society, Box 301, 79760, F.A. McElvaney. Founded 1986, 6 members.

**San Angelo** — San Angelo Amateur Astronomy Association, P.O. Box 60391, 76906, Joe Lynch, (915) 944-2113. Founded 1963, 33 members. Observatory with 12.5" telescope.

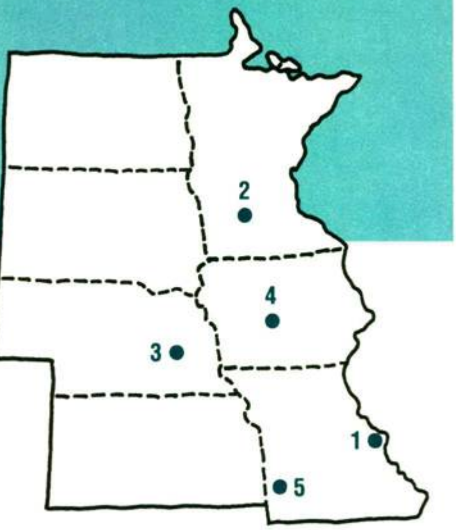
**Sanger** — Denton County Astronomical Society, 225 Green Springs Circle, 76266, John Love, (817) 458-7479.

**Stafford** — Fort Bend Astronomy Club, P.O. Box 942, 77477-0942, Dennis Zwicky, (713) 499-4993. Founded 1984, 70 members. Assists with operation of 36" scope at George Observatory.

**Texas City** — College of the Mainland Astronomy Club, Division of Natural Science, 77591, John L. Hubisz, (409) 938-4098. Founded 1971, 40 members.

**Tyler** — Astronomical Society of East Texas, c/o Hudnall Planetarium, P.O. Box 9020, 75711, Larry Scott, (214) 566-5317. Founded 1986, 50

# Midwest



**1** **July 31-August 4**
ALCON 90, joint meeting of the Astronomical League (national and mid-states region) and the Association of Lunar and Planetary Observers, Washington University, St. Louis, MO. Hosted by the St. Louis Astronomical Society. Contact: Steve Best, 6943 Amherst, St. Louis, MO 63130.

**2** **August 17-19**
Second Annual Southern Minnesota Sky Show, farm site 7 miles from New Ulm, MN. Camping. Contact: Minnesota Valley Amateur Astronomers, Route 4, Box 15A, New Ulm, MN 56073, Roger Dier, (507) 359-2488.

**3** **August 18**
Prairie Astronomy Club Picnic and Star Party, regional event for amateur astronomers, Hyde Observatory, Holmes Park, Lincoln, NE. Dark-sky observing at Atlas Observing Site, 2.5 miles southwest of Firth, NE. Contact: Prairie Astronomy Club, P.O. Box 80553, Lincoln, NE 68501, Lee Thomas, (402) 483-5639.

**4** **September 20-21**
Iowa Convention of Amateur and Professional Astronomers. Contact: C.L. Allen, c/o Des Moines Astronomical Society, 2307 49th Street, Des Moines, IA 50310-2538.

**5** **September 20-22**
Third Annual Ozarks Star Party, 12 miles south of Joplin, MO, RLDS Campground. Rain or shine. Contact: Peter Bessenbruch, 29 Williams Street, Fort Leonard Wood, MO 65473. Send SASE for details or call (314) 329-3344.

## CLUBS

### IOWA

**Ames** — Ames Area Amateur Astronomers, 1208 Wilson Avenue, 50010, David Oesper, (515) 232-8705. Founded 1979, 73 members. Monthly public star parties at McFarland Park Observatory (12.5" telescope).

**Burlington** — Southeastern Iowa Astronomy Club, 610 Walnut Street, 52601, Jim Blair, (319) 753-2509. Founded 1984, 105 members. Observatory with 11.5" refractor. Monthly public nights.

**Cedar Rapids** — Cedar Amateur Astronomers, 1513 Parkwood Lane NE, 52402, Frank Olsen, (319) 393-5758. Founded 1976, 30 members.

**Davenport** — Quad Cities Astronomical Society, P.O. Box 3706, 52808, Dana Taylor, (319) 322-2557. Founded 1980, 50 members.

**Des Moines** — Des Moines Astronomical Society, 2307 49th Street, 50310-2538, C. L. Allen. Founded 1970, 35 members. Observatory with 16" scope.

### KANSAS

**Topeka** — Northeast Kansas Amateur Astronomers League, P.O. Box 951, 66601, Brenda Culbertson, (913) 233-7528. Founded 1978, 40 members. Observatory with 17.5" scope.

**Wichita** — Kansas Astronomical Observers, P.O. Box 49013, 67202-9013, Sara Sigwing, (316) 263-7091. Founded 1978, 36 members.

### MINNESOTA

**Brainerd** — North Star Astronomy Club, 1113 9th Avenue NE, 56401, Lonnie Converse, (218) 828-4589.

**Duluth** — Arrowhead Astronomical Society, c/o Alworth Planetarium, University of Minnesota-Duluth, 55812, Glenn Langhorst, (218) 726-7129. Founded 1979, 30 members. Hosting "Northern Nights 90" at Alworth Planetarium, Aug. 4.

**Moorhead** — Fargo-Moorhead Astronomical Society, P.O. Box 28, Concordia College, 56560, Robert Brummond. Founded 1970, 20 members.

**New Ulm** — Minnesota Valley Amateur Astronomers, Route 4, Box 15A, 56073, Roger Dier, (507) 359-2488. Founded 1986, 20 members.

**St. Paul** — Minnesota Astronomical Society, 30 East 10th Street, 55101, Max Radloff, (612) 643-4092. Founded 1973, 160 members.

### MISSOURI

**Blue Springs** — Astronomical Society of Kansas City, P.O. Box 400, 64013, Gary Pittman, (816) 228-4238. Founded 1936, 180 members. Observatory with 30" telescope. Public nights two Saturdays per month.

**Florissant** — McDonnell Douglas Amateur Astronomy Club, 3491 Heather Trail Drive, 63031, Richard Melvin, (314) 569-4773.

**Fort Leonard Wood** — Ozarks Telescope Makers & Amateur Astronomers, 29 Williams Street, 65473, Peter Bessenbruch, (314) 329-3344. Founded 1987, 45 members.

**St. Peters** — St. Louis Astronomical Society, 14055 Baywood Villages, 63017, Cecelia Brown, (314) 278-1191.

### NEBRASKA

**Lincoln** — Prairie Astronomy Club, P.O. Box 80553, 68501, Lee Thomas, (402) 483-5639. Founded 1965, 70 members. Observatory with 14" SCT.

**Omaha** — Omaha Astronomical Society, 3390 South 130th Street, 68144, George Allen, (402) 333-1097.

### NORTH DAKOTA

**Bismarck** — Dakota Astronomical Society, P.O. Box 2539, 58502-2539, John R. Wetsch, (701) 256-3620. Founded 1987, 50 members.

### SOUTH DAKOTA

**Rapid City** — Black Hills Astronomical Society, 4912 Breckenridge Court, 57702, Michael O'Connor, (605) 342-3793. Founded 1954, 30 members. Observatory with 12.5" Newtonian.

## PLACES

### IOWA

**Cherokee** — Sanford Museum and Planetarium, 117 East Willow Street, 51012, (712) 225-3922. 20' dome theater. Open daily in summer.

**Des Moines** — Drake University Observatory, 50311, (515) 271-3141. Open Friday evenings.

**Des Moines** — The Science Center of Iowa/Sargent Planetarium, 4500 Grand Avenue, 50312, (515) 274-4138. 40' dome theater with Digistar projector, exhibits. Open daily, daytime only.

**Waterloo** — Grout Museum of History and Science, 503 South Street, 50701, (319) 234-6357. Open Tues.-Sat.

### KANSAS

**Greensburg** — Pallasite Meteorite, The Big Well, 315 South Sycamore, 67054, (316) 723-2261. Open daily.

**Hutchinson** — Kansas Cosmosphere & Space Center, 1100 North Plum, 67501, (316) 662-2305. Exhibits, public observing, planetarium shows, OMNIMAX® theater. Open daily in summer.

**Wichita** — Lake Afton Public Observatory, c/o 1845 Fairmount, 67208, (316) 794-8995. Exhibits, public observing (16" scope). Open Fri.-Sun. evenings.

**Wichita** — Omnisphere and Science Center, 220 South Main Street, 67202, (316) 264-3174. Exhibits, planetarium shows. Open Tues.-Sun.

### MINNESOTA

**Duluth** — Alworth Planetarium, University of Minnesota-Duluth, 55812, (218) 726-7129. Open Wed. evening only.

**Hibbing** — Paulucci Space Theater, Arrowhead Community College Region, Hwy 169 & East 23rd Street, 55746, (218) 262-6720. 40' dome theater, Cinema 360, planetarium shows, exhibits. Open daily.

**Minneapolis** — Minneapolis Planetarium, 300 Nicollet Mall, 55401, (612) 372-6644. 40' dome theater, laser shows, exhibits. Open daily in summer.

**Moorhead** — Moorhead State University Planetarium, 8th Avenue and 11th Street S, 56560, (218) 236-3982. 30' dome theater, monthly public observing. Open Thurs. evenings and by reservation.

**St. Paul** — Science Museum of Minnesota/McKnight Omnitheater, 30 E. 10th Street, 55101, (612) 291-9403. Exhibits, OMNIMAX® theater. Open daily.

### MISSOURI

**Kansas City** — Kansas City Museum Planetarium, 3218 Gladstone Boulevard, 64123, (816) 483-STAR. 24' dome theater, exhibits. Open daily in summer.

**St. Louis** — St. Louis Science Center, 5100 Clayton Avenue, Forest Park, 63110, (314) 289-4444. Exhibits, public observing, planetarium shows (60' dome). Open daily in summer.

### NEBRASKA

**Hastings** — J. M. McDonald Planetarium, Hastings Museum, 1330 North Burlington Avenue, 68901, (402) 461-2399. 24' dome theater, exhibits, observatory (14" telescope). Open daily in summer.

**Lincoln** — Hyde Memorial Observatory, Holmes Park, Golf Course Road, 68506, (402) 471-7094. 14" telescope. Open Saturday evenings.

**Lincoln** — Mueller Planetarium, University of Nebraska State Museum, 210 Morrill Hall, 68588-0338, (402) 472-2641. 34' dome theater, laser shows, exhibits. Open Tues.-Sun. in summer.

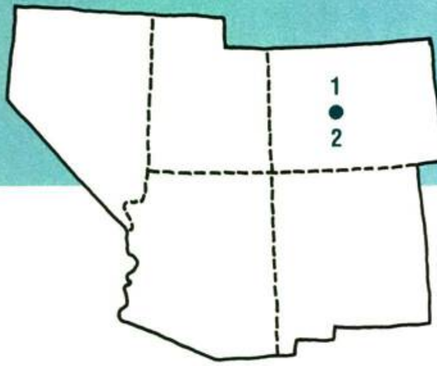
**Omaha** — Durham Science Center and Kountze Planetarium, University of Nebraska at Omaha, 68th and Dodge St., 68182, (402) 554-3727. 33' dome theater, laser shows, observatory. Open Fri.-Sun. only.

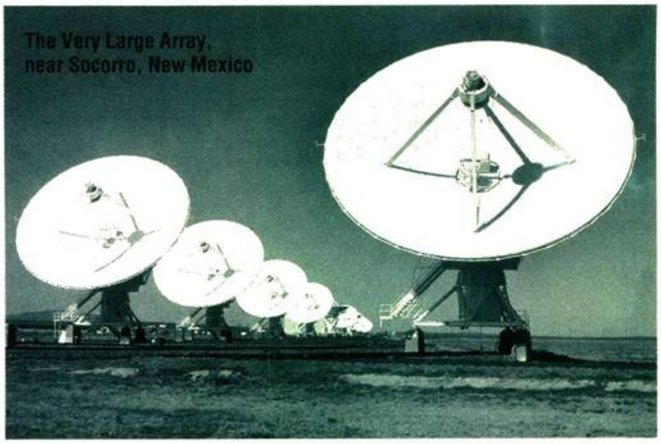
### NORTH DAKOTA

**Grand Forks** — University of North Dakota Atmospherium, Center for Aerospace Studies, P.O. Box 8216, University Station, 58202, (701) 777-2184. Exhibits, planetarium shows. Open Thurs.-Sun.

**Minot** — Minot State University Observatory, 500 University Avenue West, 58701, (701) 857-3071.

# Southwest




The Very Large Array, near Socorro, New Mexico

**1** **June 22-24**
Front Range Astronomical Supercluster Star Party, Badger Flats, near Florissant, Colorado, 55 miles west of Colorado Springs, 9,000 foot elevation. Sponsored by the Denver Astronomical Society and the Colorado Springs Astronomical Society. Contact: CSAS, P.O. Box 62022, Colorado Springs, CO 80962, Jim Lawrence, (719) 593-0801.

**2** **July 20-22**
Fourth Annual Star Stare Campout and Star Party, Badger Flats. Contact: Colorado Springs Astronomical Society, P.O. Box 62022, Colorado Springs, CO 80962, Jim Lawrence, (719) 593-0801.

## PLACES

### ARIZONA

**Amado** — Multiple Mirror Telescope Observatory, P.O. Box 97, 85645, (602) 670-6741. Tours by reservation only. Also the site of the Fred Lawrence Whipple Observatory.

**Flagstaff** — Barringer Meteor Crater, Meteor Crater Enterprises. Located 40 miles east of Flagstaff on I-40.

**Flagstaff** — Lowell Observatory, Mars Hill Road, 1400 West, 86001, (602) 774-2096. Exhibits, tours, public observing (24" Clark refractor). Open daily in summer.

**Flagstaff** — Northern Arizona University Campus Observatory, Dept. of Physics & Astronomy, Box 6010, 86011, (602) 523-2661. 24" telescope. Open Thursday evenings.

**Flagstaff** — U.S. Naval Observatory, P.O. Box 1149, 86002, (602) 527-7000.

**Tucson** — Flandrau Planetarium, University of Arizona, corner of Cherry and University Boulevard, 85721, (602) 621-4515. Exhibits, Cinema 360, laser shows, observatory. Open Tues.-Sun.

**Tucson** — Kitt Peak National Observatory, 950 North Cherry Avenue, 85719, (602) 620-5350. Visitor center at summit, exhibits, tours, lectures, films. Open daily till 4 p.m.

**Tucson** — Steward Observatory, University of Arizona, 85721, (602) 621-2288.

### COLORADO

**Boulder** — Fiske Planetarium and Science Center, University of Colorado, 80309-0408, (303) 492-5001. Exhibits, planetarium shows, laser shows, observatory. Open Mon.-Fri.

**Boulder** — National Center for Atmospheric Research (NCAR), 1850 Table Mesa Drive, 80303, (303) 497-1174. Exhibits and printed materials offered. Open daily, daytime only. Guided tours Mon.-Sat. at noon, June 4-Labor Day.

**Colorado Springs** — U.S. Air Force Academy Planetarium, 5O ATS/DOP, USAF Academy, 80840, (719) 472-2779. 50' dome theater. Open daily except Mondays in summer.

**Denver** — Gates Planetarium, Denver Museum of Natural History, 2001 Colorado Blvd., 80205, (303) 370-6351. 50' dome theater, laser shows, exhibits, IMAX® theater, observatory (22" telescope). Open daily in summer.

### NEVADA

**Las Vegas** — Clark County Community College Planetarium, 3200 East Cheyenne Avenue, 89030, (702) 644-5059. Open Thurs.-Sat. only.

**Reno** — Fleischmann Planetarium, University of Nevada-Reno, 1650 N. Virginia Street, 89557, (702) 784-4812. 30' dome theater, Cinema 360, exhibits, public observing. Open daily in summer.

### NEWMEXICO

**Alamogordo** — The Space Center, Top of New Mexico Highway 2001, 88310, (505) 437-2840. Clyde W. Tombaugh Theater (40' dome) with planetarium shows, OMNIMAX® films, laser shows, exhibits. Open daily in summer.

**Albuquerque** — University of New Mexico Observatory, Dept. of Physics and Astronomy, 800 Yale Boulevard NE, 87131, (505) 277-2616. Open Fridays and by reservation.

**Socorro** — Very Large Array, National Radio Astronomy Observatory, P.O. Box O, 87801-0387, (505) 835-7300. 27 element array of 85' dishes. Exhibits, self-guided tours. Open daily from 8:30 a.m. to sunset.

**Sunspot** — ARC Telescope, c/o New Mexico State University, Dept. of Astronomy, Box 30001, Dept. 45000, Las Cruces, 88003, (505) 646-4438. Open daily in summer.

**Sunspot** — National Solar Observatory, Sacramento Peak, 88349, (505) 434-7000. 64" telescope, guided tours every Saturday, 2pm. Open daily, daytime only.

### UTAH

**Ogden** — Layton Ott Planetarium, Weber State College, 84408, (801) 626-6855. 30' dome theater, exhibits, public observing. Open Wednesday evenings only.

**Provo** — Sarah Summerhays Planetarium, Brigham Young University, Physics Dept., 492 ESC, 84602, (801) 378-2805. Open Friday evenings only.

**Salt Lake City** — Hansen Planetarium, 15 South State Street, 84111, (801) 538-2104. Digistar projector, laser shows, exhibits. Open daily.

## CLUBS

### ARIZONA

**Gilbert** — Saguaro Astronomy Club, 5 South Pueblo Street, 85234, Gerald W. Rattley, (602) 892-5698.

**Mesa** — Leisure World Astronomers, 1792 Leisure World, 85206, Bud Ridley, (602) 981-3136.

**Phoenix** — Saguaro Astronomy Club, 2940 West Glen Drive, 85051, Peter Burggraat, (602) 995-1964. Founded 1977, 130 members.

**Scottsdale** — Phoenix Astronomical Society, 6945 East Gary Road, 85254, Raul V. Espinoza, (602) 996-3617.

**Sun City West** — Astronomy Club of Sun City West, 17802 131st Avenue, 85375, Jim Crisman, (602) 584-0896. Founded 1986, 136 members.

**Tucson** — Tucson Amateur Astronomy Association, 7222 East Brooks Drive, 85730, Terri Lappin, (602) 790-5053. Founded 1954, 120 members.

### COLORADO

**Colorado Springs** — Colorado Springs Astronomical Society, P.O. Box 62022, 80962, Jim Lawrence, (719) 593-0801. Founded 1985, 50 members.

**Colorado Springs** — Rocky Mountain Astrophysical Group, P.O. Box 25233, 80936, Paul Van Slyke, (719) 495-3828. Founded 1987, 100 members. Observatory with 18" telescope.

**Denver** — Denver Astronomical Society, P.O. Box 10814, 80210, Dave Trott, (303) 871-5172. Founded 1947, 150 members. Observatory with 20" Clark refractor.

**Longmont** — Longmont Astronomical Society, P.O. Box 8086, 80501, Bob Spohn, (303) 772-1470.

### NEVADA

**Elko** — Elko Astronomical Society, 550 South 12th #22, 89801, Len Seymour, (702) 738-7916. Founded 1987, 15 members.

**Las Vegas** — Las Vegas Astronomical Society, Clark County Community College, 3200 East Cheyenne Avenue, 89030, John Ruff, (702) 459-8401. Founded 1980, 125 members.

**Reno** — Astronomical Society of Nevada, 825 Wilkinson Avenue, 89502, Italo Gavazzi, (702) 329-9946.

### NEWMEXICO

**Alamogordo** — Alamogordo Amateur Astronomers, 1210 Filipino, 88310, Paula Hamilton, (505) 434-0115.

**Albuquerque** — Albuquerque Astronomical Society, P.O. Box 54072, 87153, Dave Finley, (505) 291-0402. Founded 1958, 250 members.

**Hobbs** — Lea County Astronomical Society, NMJC Science Building, 5317 Lovington Highway, 88240, V.G. Berner, (505) 392-4510. Founded 1977, 20 members.

### UTAH

**Cedar City** — Southern Utah Astronomy Group, 147 South 300 East, 84720, Brent Sorensen, (801) 586-2759.

**Roy** — Ogden Astronomical Society, 2336 West 5650 South, 84067, Bob Tillotson, (801) 773-8106.

**Salt Lake City** — Salt Lake City Astronomical Society, c/o Hansen Planetarium, 15 South State Street, 84111, David Bernson, (801) 467-2126. Founded 1968, 120 members. Observatory. Star parties twice a month.

## NATIONAL ORGANIZATIONS

**Amateur Satellite Observers,** HCR 65, Box 261-B, Kingston, AR 72742, Jim Hale.

**American Association of Variable Star Observers,** 25 Birch Street, Cambridge, MA 02138, (617) 354-0484, Janet Mattei.

**American Astronomical Society,** 2000 Florida Avenue NW, Suite 300, Washington, D.C. 20009, (202) 328-2010, Peter B. Boyce.

**American Lunar Society,** P.O. Box 209, East Pittsburgh, PA 15112, (412) 829-7455, Francis Graham. Founded 1984, 102 members.

**American Meteor Society,** Dept. of Physics-Astronomy, SUNY Geneseo, Geneseo, NY 14454, (716) 245-5282, David Meisel. Founded 1910, 100 members. Also via Electronic Mail: Bitnet MEISEL@GENESEO.

**Association of Lunar and Planetary Observers,** P.O. Box 143, Heber Springs, AZ 72543, Harry Jamieson, membership secretary. Founded 1947, 700 members.

**Astronomical League,** 6235 Omie Circle, Pensacola, FL 32504-7625, (904) 477-8859, Merry Wooten.

**Astronomical Society of the Pacific,** 390 Ashton Avenue, San Francisco, CA 94112, (415) 337-1100. Founded 1889, 7,000 members.

**Astronomy Day Headquarters,** c/o Chaffee Planetarium, 54 Jefferson SE, Grand Rapids, MI 49503, (616) 456-3985, Gary Tomlinson. Founded 1973.

**Aurora Alert Hotline,** Manley Drive, RR #1, Box 232A, Pascoag, RI 02859, (401) 568-9370, David A. Huestis.

**Earthwatch,** Box 403, Watertown, MA 02272, (617) 926-8200, Blue Magruder. Founded 1971, 45,000 members. Sponsors scientific field research worldwide.

**International Amateur-Professional Photoelectric Photometry,** c/o Arthur J. Dyer Observatory, Vanderbilt University, Nashville, TN 37235, (615) 373-4897, Douglas Hall. 800 members.

**International Dark-Sky Association,** 3545 N. Stewart, Tucson, AZ 85716, David Crawford.

**International Occultation Timing Association,** P.O. Box 7488, Silver Spring, MD 20901, (301) 495-9062, David W. Dunham. 300 members.

**International Planetarium Society,** c/o Hansen Planetarium, 15 S. State Street, Salt Lake City, UT 84111.

**National Deep Sky Observers Society,** 3123 Radiance Road, Louisville, KY 40220, (502) 458-5541, Alan Goldstein. Founded 1976, 110 members.

**National Space Society,** 922 Pennsylvania Avenue SE, Washington, D.C. 20003, (202) 543-1900, Aleta Jackson.

**Problicom Sky Survey and Nova Patrol,** 1940 Cotner Avenue, Los Angeles, CA 90025, (213) 478-2526, Ben Mayer. Founded 1974, 250 members. Free quarterly newsletter, send 4 to 6 SASE's.

**Small Scope Observers Association,** 4 Kingfisher Place, Audubon Park, NJ 08106, (609) 547-9487, Robert Browning. Founded 1986, 116 members.

**Society for Scientific Exploration,** P.O. Box 3818, Charlottesville, VA 22903, (804) 924-4905, L.W. Frederick.

**Society of Amateur Radio Astronomers,** 247 North Linden St., Massapequa, NY 11758, Vincent Caracci. Founded 1981, 200 members.

**Spaceweek National Headquarters,** P.O. Box 58172, Houston, TX 77258.

**Sunsearch Supernova Patrol,** 14400 Kolin Avenue, Midlothian, IL 60445, (708) 396-1499, Steve H. Lucas. Founded 1985, 25 members.

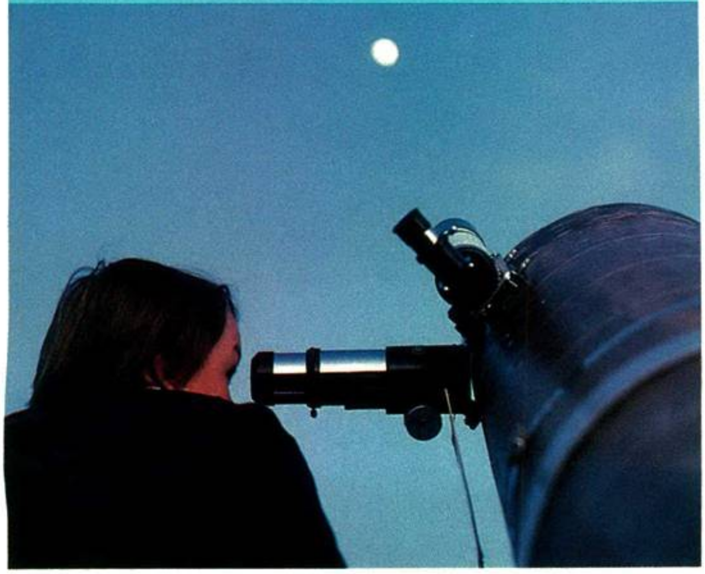
**The Meteoritical Society,** c/o Department of Geological Sciences, University of Tennessee, Knoxville, TN 37996. Founded 1933, 850 members.

**The Planetary Society,** 65 North Catalina Avenue, Pasadena, CA 91106, (818) 793-5100, Susan Lendroth. Founded 1980, 125,000 members.

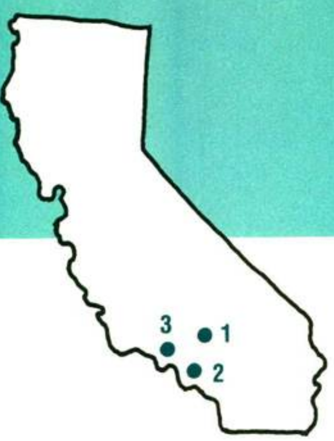
**Webb Society (North America),** 1440 S. Marmora Avenue, Tucson, AZ 85713, (602) 628-1077, Ron Morales. 200 members.

**Western Amateur Astronomers,** 163 Starlight Crest Drive, La Canada, CA 91011, Stephen Edberg.

**World Space Foundation,** P.O. Box Y, South Pasadena, CA 91030-1000, (818) 357-2878, Jack Child.



# California



**1** **May 25-28**
Riverside Telescope Makers Conference, Big Bear Lake area, CA. Speakers include Clyde Tombaugh, Brian Marsden, and Jim Christy.The Western Amateur Astronomers will also meet. Contact: Cliff Holmes, (714) 689-6893, or write Riverside Astronomical Society, P.O. Box 51222, Riverside, CA 92517-2222.

**2** **August 25**
Summer Star Party of the Orange County Astronomers, Public Observatory, Mile Square Park, 4-10 p.m. Contact: Orange County Astronomers, 2215 Martha Avenue, Orange, CA 92667, John Sanford, (714) 639-8446.

**3** **September 14**
Santa Monica Amateur Astronomy Club Annual Open House. Lectures, exhibits, observing. Starts at 7:30 p.m. Public welcome. Contact: Robert Lozano, 1415 Michigan Ave., Santa Monica, CA 90404, (213) 450-1944.

## PLACES

**Apple Valley** — Apple Valley Science and Technology Center, 22974 Bear Valley Road, 92308, (619) 247-7267.

**Berkeley** — Lawrence Hall of Science, University of California, 94720, (415) 642-5362. Exhibits, planetarium shows (20' dome). Open daily in summer. Saturday night stargazing, 9-11 p.m.

**Big Bear City** — Big Bear Solar Observatory, 40386 North Shore Lane, 92314, (714) 866-5791. Open Saturdays 4-6 p.m., July 4-Labor Day.

**Cassel** — Hat Creek Radio Observatory, University of California, Berkeley, Rt. 2 Box 500, 96016, (916) 335-2364. 85' dish and three 20' dishes. Open Mon.-Fri.

**Edwards** — Ames Research Center, Hugh L. Dryden Flight Research Facility, 93523, (805) 258-3446.

**Fresno** — The Discovery Center Museum of Natural Science, 1944 North Winery Avenue, 93703, (209) 251-5533.

**Los Angeles** — California Museum of Science & Industry, Exposition Park, 700 State Drive, 90037, (213) 744-7483. Exhibits, space artifacts, IMAX® theater. Open daily.

**Los Angeles** — Griffith Observatory, 2800 East Observatory Road, 90027, (213) 664-1181. 75' dome theater, laser shows, exhibits, observatory (12" Zeiss refractor). Open daily in summer.

**Moffett Field** — NASA Ames Research Center, c/o Office of Public Information, Mail Stop 204-12, 94035, (415) 604-6472. Exhibits. Open Mon.-Fri. daytime only. Tours by reservation.

**Mount Hamilton** — Lick Observatory, P.O. Box 55, 95140, (408) 274-5062, 120" and 40" reflectors, 36" refractor. Open daily, daytime only. Public observing through 40" and 36" on Friday nights, July 6-Aug. 31 by reservation only.

**Oakland** — Chabot Observatory and Planetarium, 4917 Mountain Boulevard, 94619, (415) 531-4560. 30' dome theater, 20" refractor, exhibits. Open Fri. & Sat. evenings. Closed August.

**Owens Valley** — Owens Valley Radio Observatory, c/o Robinson Laboratory, California Institute of Technology, Pasadena, 91125, (818) 356-4912.

**Pasadena** — Jet Propulsion Laboratory, 4800 Oak Grove, 91109, (818) 354-7006.

**Pasadena** — Mount Wilson Observatory, Mount Wilson Institute, 740 Holladay Road, 91106, (818) 793-3100. Historic 100" and 60" reflectors.

**Pasadena** — Palomar Observatory, Palomar Mountain, c/o California Institute of Technology, 91125, (619) 742-2119. 200" Hale Telescope. Open daily in summer, daytime only.

**Redding** — Schreder Planetarium, 1644 Magnolia Avenue, 96001, (916) 244-4600. 33' dome theater. Open Friday evenings only.

**Rohnert Park** — Sonoma State University Observatory, Dept. of Physics and Astronomy, 94928, (707) 664-2119. 14" telescope. Open one evening per month.

**Sacramento** — Sacramento Science Center, 3615 Auburn Boulevard, 95821, (916) 449-8255. Exhibits, planetarium shows. Open daily, afternoons only.

**San Diego** — Reuben H. Fleet Space Theater and Science Center, 1875 El Prado, Balboa Park, 92101, (619) 238-1233. 76' dome theater with planetarium shows, laser shows, OMNIMAX® films. Open daily.

**San Francisco** — Exploratorium, 3601 Lyon Street, 94123, (415) 563-7337. Extensive science exhibits. Open Wed.-Sun. daytime only and Wed. evenings.

**San Francisco** — Morrison Planetarium, California Academy of Sciences, Golden Gate Park, 94118, (415) 750-7141. Exhibits, planetarium shows, laser shows. Open daily.

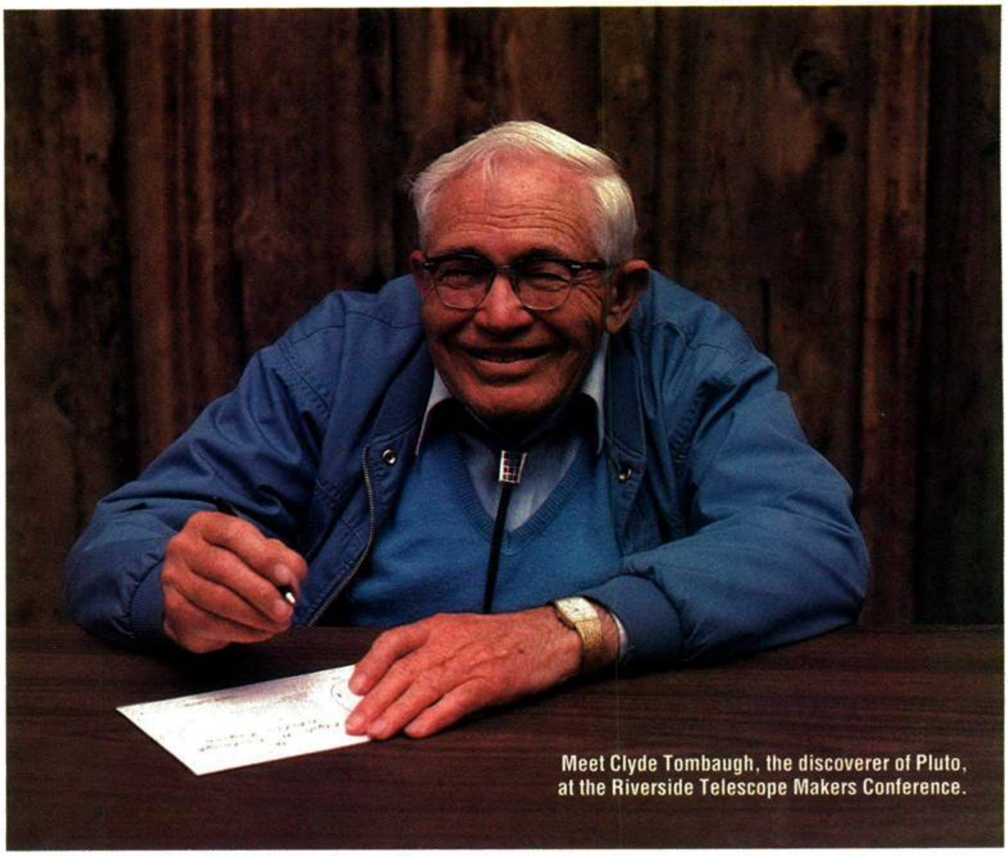
**San Jose** — Rosicrucian Planetarium and Science Center, Park & Nagalee Avenue, 95191, (408) 287-9171. 40' dome theater, exhibits. Open daily in summer, daytime only.

**Santa Barbara** — Gladwin Planetarium/Palmer Observatory, Santa Barbara Museum of Natural History, 2559 Pursta del Sol Road, 93105, (805) 682-4711. Open daily, planetarium open Sat. & Sun.

**Santa Monica** — Santa Monica College Planetarium, 1900 Pico Boulevard, 90405, (213) 452-9223. 28' dome theater, observatory (10" telescope). Open Friday evenings.

**Santa Rosa** — Santa Rosa Junior College Planetarium, 1501 Mendocino Avenue, 95401, (707) 527-4640. 40' dome theater, public observing. Open Fri. & Sat. evenings only.

**Stockton** — Clever Planetarium and Earth Science Center, Delta College, 5151 Pacific Avenue, 95207, (209) 474-5051. 33' dome theater, Cinema 360, exhibits. Open Fri.-Sun. evenings only.



Meet Clyde Tombaugh, the discoverer of Pluto, at the Riverside Telescope Makers Conference.

## CLUBS

**Aptos** — Cabrillo Astronomical Stargazing Society, Cabrillo College, Student Affairs Office, 6500 Soquel Drive, 95003. Founded 1985, 24 members. Monthly star parties at Cabrillo College.

**Berkeley** — Sidewalk Astronomers, P.O. Box 10003, 94709, Gerald Pardeilhan, (415) 527-4026.

**Chatsworth** — Celestial Observers, 9534 Gierson Avenue, 91311, Michael Selden, (818) 882-6172. Founded 1977, 14 members.

**Cucamonga** — Pomona Valley Amateur Astronomers, 8773 Balsa Street, 91730. Bob Hibble, (714) 989-3680.

**Fallbrook** — Telescope Astronomical Society, 929 Buena Rosa Court, 92028.

**Fresno** — Central Valley Astronomers, 5790 East Tarpey Avenue, 93727, Clarence Funk, (209) 291-7879. Founded 1952, 52 members. 20" portable telescope. Monthly public star parties.

**Hemet** — Hemet Astronomical Society, 561 West Devonshire Avenue, 92343, Ralph L. Shook, (714) 658-3631.

**Idyllwild** — Idyll-Gazers Amateur Astronomy Club, P.O. Box 1245, 92349, Joe Neu, (714) 659-3562.

**Lancaster** — Antelope Valley Astronomical Society, P.O. Box 426, 93534, Steve Mathis, (805) 256-4261.

**Los Angeles** — Los Angeles Astronomical Society, 2800 East Observatory Road, 90027, Timothy Thompson, (213) 833-1733. Founded 1926, 350 members. Observatory with 31" reflector.

**Marin County** — Mt. Tamalpais Observers, Mt. Tamalpais State Park, Tinka Ross, (415) 454-4715. Sponsors monthly lectures and public observing on Saturdays near New Moon.

**Moraga** — Astronomical Association of Northern California, 731 Camino Ricardo, 94556. Don Stone, (415) 376-3007.

**Mountain View** — Peninsula Astronomical Society, P.O. Box 4542, 94040, Bill Sorrells, (415) 566-3116.

**Newhall** — The Local Group Astronomy Club of Santa Clarita Valley, 25032 Walnut Street, 91321. LaVerne Booth, (805) 259-3284. Founded 1984.

**Oceanside** — Oceanside Photo and Telescope Astronomical Society, 1024 Mission Avenue, 92054, (619) 722-3343. Founded 1982, 110 members. 8th Annual Summer Telescope Demonstration May 19, 10 a.m.-10 p.m.

**Orange** — Orange County Astronomers, 2215 Martha Avenue, 92667, John Sanford, (714) 639-8446. Founded 1967, 535 members. Observatory with 22" Cassegrain.

**Palm Desert** — Astronomical Society of the Desert, c/o College of the Desert, 45-300 Monterey Avenue, 92264. Ashley McDermott, (619) 346-8041.

**Riverside** — Riverside Astronomical Society, P.O. Box 51222, 92517-2222, Cliff Holmes, (714) 689-6893. Founded 1956, 100 members.

**Rocklin** — Sacramento Valley Astronomical Society, P.O. Box 575, 95677. R. S. Marasso, (916) 624-3333.

**Salinas** — Space Frontier Society of the Monterey Bay Area, P.O. Box 9382, 93915-9382. Oscar G. Garcia, (408) 757-2725.

**San Bernardino** — San Bernardino Amateur Astronomers, 1345 Garner Avenue, 92411, Bob Harrington, (714) 875-1320. Founded 1958, 70 members.

**San Diego** — San Diego Astronomy Association, P.O. Box 23215, 92123, Greg Cade, (619) 560-1155. Founded 1963, 350 members. Observatory with 22" telescope.

**San Diego** — San Diego L5 Society, P.O. Box 4636, 92104, Albert Schafer, (619) 295-3690. 1,200 members.

**San Francisco** — S.T.A.R.S., c/o City College of San Francisco, 50 Phelan Avenue, 94112, Don Warren, (415) 239-3242. Founded 1969, 25 members. Observatory with Celestron 14.

**San Francisco** — San Francisco Amateur Astronomers, c/o Josephine D. Randall Museum, 114 Museum Way, 94114, Irving Hochman, (415) 641-0770. Founded 1952, 150 members. Star parties on Mt. Tamalpais.

**San Jose** — San Jose Astronomical Association, 3509 Calico Avenue, 95124, Jim Van Nuland, (408) 371-1307. Founded 1954, 350 members. Monthly star parties at Branham Lane City Park.

**San Juan Bautista** — Fremont Peak Observatory Association, Fremont State Park, P.O. Box 1110, 95045, Rick Morales, (408) 623-4255. Founded 1985, 175 members. Observatory with 30" reflector. Public observing on Saturday nights.

**San Luis Obispo** — Central Coast Astronomical Society, P.O. Box 1415, 93406, Lee Coombs, (805) 528-6682. Founded 1979, 60 members.

**San Marcos** — Astronomical Society of Southern California, P.O. Box 2046, 92069, Michael Wartenberg, (619) 741-6128.

**San Mateo** — San Mateo Astronomical Society, P.O. Box 974, Station A, 94403, Bob Bruynesteyn. Founded 1960, 50 members.

**Santa Barbara** — Santa Barbara Astronomy Club, P.O. Box 3702, 93130, Clyde Kirkpatrick, (805) 685-2705. Founded 1919, 54 members. Observatory with 16.5" telescope. Star party August 11.

**Santa Cruz** — Santa Cruz Astronomy Club, L-2 San Carlos Lane, 95065, James M. Bricken, (408) 335-2450.

**Santa Monica** — Santa Monica Amateur Astronomy Club, 1415 Michigan Avenue, 90404, Robert Lozano, (213) 450-1944. Founded 1981, 35 members.

**Santa Rosa** — Sonoma County Amateur Astronomers, P.O. Box 183, 95402, Robert Ferguson, (707) 762-2064.

**Simi Valley** — Ventura County Astronomical Society, P.O. Box 982, 93062, Hal Jandorf, (805) 529-3984.

**Tulare** — Tulare Astronomical Association, P.O. Box 515, 93275, Stanley H. Manro, (209) 686-6836. Founded 1968, 100 members. Operates Arthur Pursell Observatory/Visitor Center.

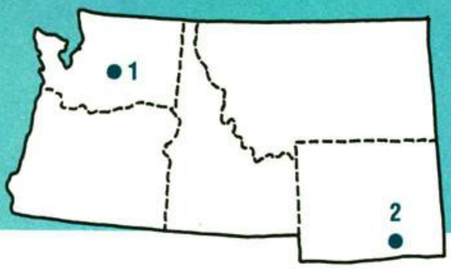
**Van Nuys** — Los Angeles Valley College Astronomy Club, 5800 Fulton Avenue, 91401, Bruce Dale, (818) 781-1200. Founded 1985, 30 members.

**Vandenberg AFB** — Vandenberg Amateur Astronomical Society, P.O. Box 5321, 93437, Luis Nieves-Aviles, (805) 734-2768. 20 members.

**Walnut Creek** — Mount Diablo Astronomical Society, 1725 Sunnyvale Avenue, 94596, Paul H. Cragey, (415) 676-6046.

**Woodland Hills** — Polaris Astronomical Association, 22018 Ybarra Road, 91364, Ray G. Coutchie, (818) 347-8922.

# Northwest and Pacific



**1** **July 20-21**
Astronomical League (Northwest Region), Table Mountain, Ellensburg, WA. Contact: Tom Jenkins, S. 3312 Pittsburgh, Spokane, WA 99203, (509) 838-1381.

**2** **August 17-19**
Mountain Astronomers Rendezvous and Star Party, held under the dark skies of southern Wyoming, Fox Park near Laramie. Contact: Denver Astronomical Society, P.O. Box 10814, Denver, CO 80210, Dave Trott, (303) 871-5172.

## PLACES

### ALASKA

**Fairbanks** — Geophysical Institute, University of Alaska-Fairbanks, Elvey Building, 99775, (907) 474-7598.

**Juneau** — Marie Drake Planetarium, 1250 Glacier Avenue, 99801, (907) 586-3780.

### HAWAII

**Honolulu** — Bernice P. Bishop Museum and Planetarium, 1525 Bernice Street, P.O. Box 19000-A, 96817, (808) 848-4102. 30' dome theater, exhibits, observatory (12.5" telescope). Open daily.

**Honolulu** — Mauna Kea Observatories, c/o Institute for Astronomy, 2680 Woodlawn Drive, 96822, (808) 948-8312. Four-wheel drive vehicle recommended for drive to the summit of Mauna Kea on the Big Island. Visitor center at 9,000-foot level.

**Kamuela** — Canada-France-Hawaii Telescope, Mauna Kea, P.O. Box 1597, 96743, (808) 885-7944. 3.6-meter telescope. Viewing gallery.

### MONTANA

**Bozeman** — Taylor Planetarium, Museum of the Rockies, Montana State University, 7th and Kagy, 59717, (406) 994-2251. 40' dome theater with Digistar projector. Open daily.

### OREGON

**Bend** — Pine Mountain Observatory, University of Oregon, Bend-Burns Star Route, 97702, (503) 382-8331. 32" and 24" telescopes. Open by reservation only.

**Portland** — Oregon Museum of Science & Technology/Kendall Planetarium, 4015 SW Canyon Road, 97221, (503) 222-2828. 40' dome theater, laser shows, exhibits. Open daily.

**Salem** — Chemetka Community College Planetarium, 4000 Lancaster Drive, N.E., P.O. Box 14007, 97309, (503) 399-5761. Open Fri. & Sat.

### WASHINGTON

**Goldendale** — Goldendale Observatory State Park, 1602 Observatory Drive, 98620, (509) 773-3141. 24.5" telescope plus 2" to 18" portables. Open daily in summer.

**Seattle** — Pacific Science Center, 200 Second Avenue North, 98109, (206) 443-2001. Exhibits, planetarium shows (27' dome), laser shows, IMAX® theater. Open daily. Astronomy Hotline 443-2920.

**Spokane** — Eastern Washington Science Center, Riverfront Park, 99202, (509) 359-6391. Exhibits, planetarium shows. Open daily.

### WYOMING

**Casper** — Casper Planetarium, 904 North Poplar Street, 82601, (307) 557-0310. 30' dome theater, public observing. Open 7:30 p.m. each evening June 10-Labor Day.

**Laramie** — University of Wyoming Planetarium, Dept. of Physics and Astronomy, University Station, Box 3905, 82071, (307) 766-6150.

**Laramie** — Wyoming Infrared Observatory, University of Wyoming, University Station, Box 3905, 82071, (307) 766-6150.

## CLUBS

### ALASKA

**Anchorage** — Anchorage Astronomical Society, 3539 Dunkirk Drive, 99502, John Morrow, (907) 269-5744.

**Fairbanks** — Astronomical Units, Box 82210, 99708, Robert E. Fischer, (907) 456-6586. Founded 1986, 15 members. Observatory.

### AMERICANSAMOA

**Pago Pago** — American Samoa Astronomical Society, P.O. Box 3076, 96799.

### HAWAII

**Captain Cook** — Mauna Kea Astronomical Society, 84-5095 Hawaii Belt Road, 96704, Howard Yamasaki, (808) 328-9201. Founded 1980, 50 members. Monthly star parties at 9,200-foot level visitors center.

**Honolulu** — Hawaiian Astronomical Society, P.O. Box 17671, 96817, Kayoko Calef, (808) 531-4567.

**Makawao, Maui** — Maui Astronomy Club, 325 Olokani Street, 96768, Bob Bennett, (808) 572-1939.

### IDAHO

**Boise** — Boise Astronomical Society, P.O. Box 8386, 83707, Art Martini, (208) 362-2074. Founded 1982, 70 members.

### OREGON

**Eugene** — Eugene Astronomical Society, Lane ESD Planetarium, P.O. Box 2680, 97402, Cuyla Shelton, (503) 345-7748. Founded 1959, 80 members.

**Portland** — OMSI Astronomers, 4015 SW Canyon Road, 97221, John Buting, (503) 228-OMSI.

**Portland** — Portland Astronomical Society, 2626 SW Luradel, 97219, Don Botteron, (503) 245-6251.

**Roseburg** — Umpqua Amateur Astronomers, Umpqua Community College, 3150 West Military Avenue, 97470, Paul Morgan, (503) 673-1081. Founded 1987, 20 members.

**Veronia** — Northwest Astronomy Group, 55371 McDonald Road, 97064, Sandy Mikalow, (503) 429-2430. Founded 1980, 50 members.

### WASHINGTON

**Bellingham** — WACO-Whatcom Association of Celestial Observers, 3700 Taylor Avenue, 98226, Tom Masterson, (206) 734-5821. Founded 1988.

**Centralia** — Southwest Washington Astronomical Society, 2421 Leisure Lane, 98531, Carl M. Newton, (206) 736-6144. Founded 1975, 50 members.

**Keyport** — Olympic Astronomical Society, P.O. Box 458, 98345, Roger Miller, (206) 698-0381. Founded 1969, 85 members.

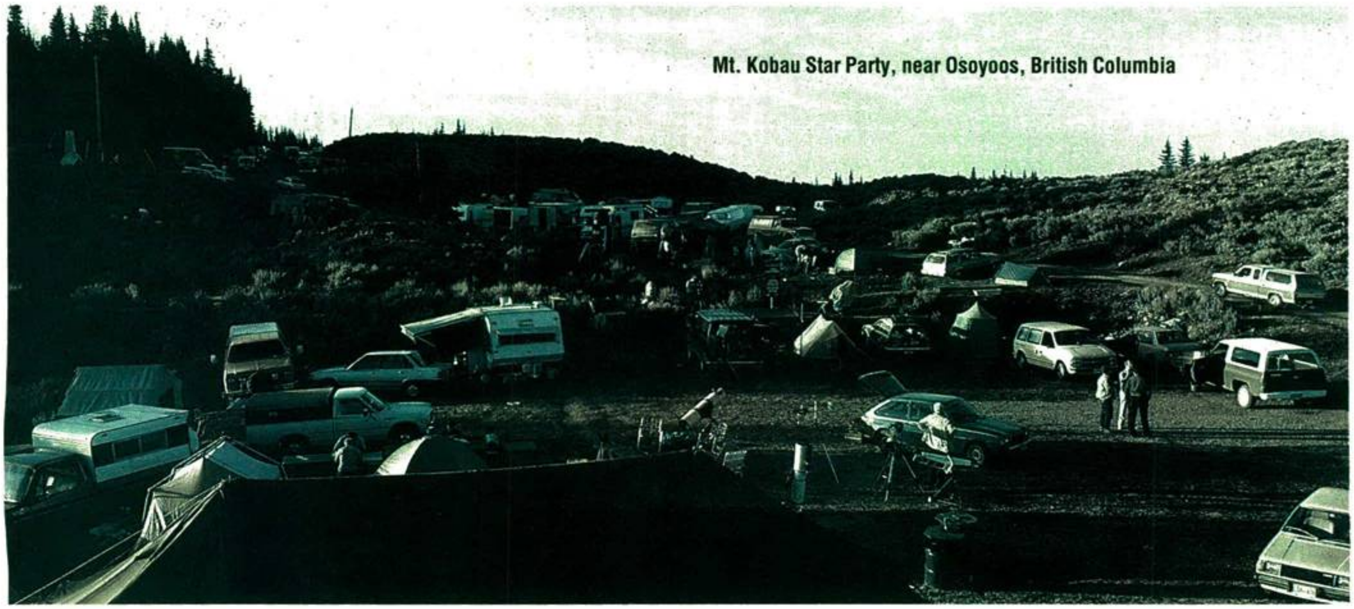
**Richland** — Tri-City Astronomy Club, 1725 Birch, 99352, Thomas L. Page, (509) 946-9803. Founded 1983, 43 members.

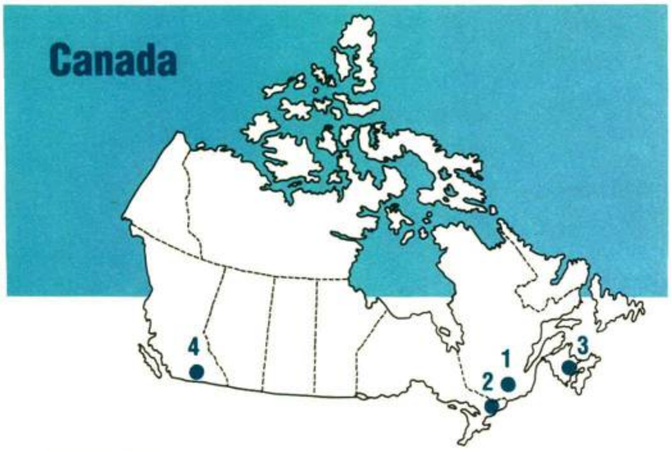
**Seattle** — Boeing Employees Astronomical Society, The Boeing Company, P.O. Box 3707, Mail Stop 4H-58, 98124, Walter Hazen, (206) 657-6488. Founded 1980, 100 members. 20" portable telescope.

**Spokane** — Spokane Astronomical Society, P.O. Box 8114, 99203-8114, Thom Jenkins, (509) 838-1381. Founded 1936, 85 members.

### WYOMING

**Cheyenne** — Cheyenne Astronomical Society, 3409 Frontier Street, 82001, Marcy Flint, (307) 634-2717. Founded 1986, 40 members.


**Mt. Kobau Star Party, near Osoyoos, British Columbia**



**1** **June 29-July 3**
General Assembly of the Royal Astronomical Society of Canada, Ottawa, Ontario. Centennial celebration. Contact: The Ottawa Centre-R.A.S.C., P.O. Box 6617, Station J, Ottawa, Ontario, Canada K2A 3Y7.

**2** **August 17-18**
Starfest '90, observing convention of the North York Astronomical Association, Riverplace Campground, Mount Forest, Ontario. Contact: Andreas Gada, 26 Chryessa Avenue, Toronto, Ontario, Canada M6N 4T5, (416) 761-1798.

**3** **August 17-20**
Nova East '90 Star Party, Fundy National Park, New Brunswick. Talks, dark-sky observing. Contact: Halifax Centre of the R.A.S.C., 1747 Summer Street, Halifax, Nova Scotia, Canada B3H 3A6.

**4** **August 22-26**
Mount Kobau Star Party, near Osoyoos, British Columbia on the Canada/U.S. border. Held on the summit of Mount Kobau. Contact: Peter Kuzel, 4100 25th Avenue, Vernon, B.C., Canada V1T 1P4, (604) 545-1226.

## PLACES

### ALBERTA

**Calgary** — Alberta Science Centre/Centennial Planetarium, P.O. Box 2100, 701-11 Street SW, T2P 2M5, (403) 221-3700. 65' dome theatre, exhibits, laser shows, observatory. Open daily in summer.

**Edmonton** — Edmonton Space Sciences Centre, 11211-142 Street, T5M 4A1, (403) 452-9100. Exhibits, planetarium shows (76' dome), laser shows, IMAX® theatre, observatory. Open daily in summer. Astronomy Newsline 455-STAR.

### BRITISH COLUMBIA

**Penticton** — Dominion Radio Astrophysical Observatory, Box 248, V2A 6K3, (604) 497-5788. Open daily. Guided tours, Sundays 2-5 p.m.

**Vancouver** — H.R. MacMillian Planetarium & Gordon Southam Observatory, 1100 Chestnut Street, V6J 3J9, (604) 736-3656. Exhibits, planetarium shows (65' dome), laser shows, observatory (20" telescope). Open daily in summer.

**Vancouver** — Science World, 1455 Quebec Street, V6A 3Z7, (604) 687-8414. Exhibits, OMNIMAX® theatre. Open daily, daytime only. Call 687-7832 for recorded information.

**Vancouver** — University of British Columbia Observatory, 2219 Main Mall, V6R 2Z7, (604) 228-2802. 16" telescope. Open clear Saturday evenings. Call 228-6186 to confirm.

**Victoria** — Dominion Astrophysical Observatory, National Research Council of Canada, 5071 West Saanich Road, V8X 4M6, (604) 388-0001. Exhibits, tours, public observing Saturday evenings. Open Mon.-Fri. daytime only.

### MANITOBA

**Winnipeg** — Manitoba Planetarium, Museum of Man & Nature, 190 Rupert Avenue, R3B 0N2, (204) 956-2830. 60' dome theatre, laser shows, Touch The Universe exhibit gallery. Open daily.

### NOVA SCOTIA

**Halifax** — Burke-Gaffney Observatory, Saint Mary's University, B3H 3C3, (902) 420-5633. Open Sat. evenings.

### ONTARIO

**Ottawa** — National Museum of Science & Technology, 1867 St. Laurent Boulevard, K1G 5A3, (613) 991-9219. Exhibits, observatory (15" refractor). Public observing every Tuesday evening (in French) and every Wednesday and Thursday evening (English) during July and August.

**Richmond Hill** — David Dunlap Observatory, Box 260, 123 Hillsview Drive, L4C 4Y6, (416) 884-2112. 1.9-meter reflector. Tours Tuesday mornings and public observing Saturday evenings, both by reservation only.

**Sudbury** — Science North Science Centre, 100 Ramsey Lake Road, P3E 5S9, (701) 522-3701. Exhibits, interactive "Starwall," solar observatory. Open daily, daytime only.

**Toronto** — McLaughlin Planetarium, Royal Ontario Museum, 100 Queen's Park, M5S 2C6, (416) 586-5736. 75' dome theatre, exhibits, laser shows. Open Tues.-Sun.

**Toronto** — Ontario Science Centre, 770 Don Mills Road, M3C 1T3, (416) 429-4100. Extensive science exhibits, space artifacts, planetarium shows. Open daily.

### QUEBEC

**Notre Dame Des Bois** — Mont Megantic Observatory, Chemin de Lamontagne, J0B 2E0, (819) 888-2822. 63-inch reflector. Open daily in summer. Public observing July 13 & 14 during the Festival d'Astronomie Populaire.

**Montreal** — Dow Planetarium, 1000, St. Jacques Ouest, H3C 1G7, (514) 872-4530. 65' dome theatre. Open daily. Alternating schedule of French and English programs.

### SASKATCHEWAN

**Regina** — Saskatchewan Science Centre, Winnipeg Street and Wascana Drive, P.O. Box 5071, S4P 3M3, (306) 352-2797. Open Tues.-Sun. and holiday Mondays. Call 352-5811 for recorded information.

**Saskatoon** — University of Saskatchewan Observatory, S7N 0W0, (306) 966-6396. 6" Clark refractor, exhibits. Open Saturday evenings only.

## CLUBS

### BRITISH COLUMBIA

**Prince George** — Prince George Astronomical Society, College of New Caledonia, 3330-22nd Avenue, V2N 1P8, Bob Nelson, (604) 562-2131.

**Vancouver** — RASC-Vancouver Centre, c/o Gordon Southam Observatory, 1100 Chestnut Street, V6J 3J9.

**Vernon** — Okanagan Astronomical Society, 4100 25th Avenue, V1T 1P4, Peter Kuzel, (604) 545-1226.

**Victoria** — RASC-Victoria Centre, 801 Stanehill Place, RR #1, V8X 3W9, A. Newton, (604) 478-8065.

### ALBERTA

**Calgary** — RASC-Calgary Centre, c/o Alberta Science Centre, P.O. Box 2100, Station M, T2P 2M5. 200 members. Operates Wilson Coulee Observatory.

**Edmonton** — RASC-Edmonton Centre, 4203-106 B Avenue, T6A LK7, Mel Rankin. Founded 1932, 120 members. 17.5" Dobsonian telescope.

**Fort McMurray** — Astronomical Society of Fort McMurray, 203 Oaks Crescent, T9K 1M4, Shelia Callan, (403) 743-9178. Founded 1986, 20 members.

**Lethbridge** — Lethbridge Astronomy Society, P.O. Box 1104, T1J 4A2, Rick Ponomar, (403) 381-1332. Founded 1988, 30 members.

### SASKATCHEWAN

**Regina** — RASC-Regina Centre, P.O. Box 6735, S4S 7E6. Founded 1989, 30 members.

**Saskatoon** — RASC-Saskatoon Centre, Box 317, Sub. P.O. Box #6, S7N 0W0, Jim Young, (306) 652-1536.

### MANITOBA

**Brandon** — Westman Amateur Astronomy Club, 32 Ashgrove Blvd., R7B 1C2, Jeff Harland, (204) 726-8294. Founded 1985, 40 members.

**Winnipeg** — Manitoba Astronomy Club, 190 Rupert Avenue, R3B 0N2, Doug Knight, (204) 956-2830. Junior astronomers club.

**Winnipeg** — RASC-Winnipeg Centre, P.O. Box 215, St. James Post Office, R3J 3R4. Operates Glenlea Observatory.

### ONTARIO

**Belle River** — RASC-Windsor Centre, 453 East Belle River Road, RR 2, N0R 1A0, Lorison Durocher, (519) 728-1332. Founded 1943, 71 members.

**Kingston** — RASC-Kingston Centre, P.O. Box 1793, K7L 5J6, Denise Sabatini. Founded 1961, 35 members.

**London** — RASC-London Centre, P.O. Box 842, Station B, N6A 4Z3. Founded 1922, 50 members.

**Ottawa** — RASC-Ottawa Centre, P.O Box 6617, Station J, K2A 3Y7. Founded 1906, 250 members. Observatory with 16" reflector.

**Sarnia** — RASC-Sarnia Centre, c/o Box 103, Wyoming, Ontario, N0N 1T0, Derek Hitchens.

**St. Catharines** — RASC-Niagara Centre, 59 Chancery Circle, John Dekker, (416) 934-7210. Founded 1958, 80 members.

**Sudbury** — Sudbury Astronomy Club, 859 Chestnut Crescent, P3A 5B3, Fred Boyer, (705) 560-3265.

**Thunder Bay** — RASC-Thunder Bay Centre, c/o Mrs. B. Connell, 545 Parkway Drive, P7A 5C9. Founded 1988, 30 members.

**Toronto** — North York Astronomical Association, 26 Chryessa Avenue, M6N 4T5, Andreas Gada, (416) 761-1798. Founded 1980, 50 members, Observatory with 16" Dobsonian.

**Toronto** — RASC-Toronto Centre, McLaughlin Planetarium, 100 Queen's Park, M5S 2C6, Guy Nason, (416) 222-4814. Founded 1868, 1,040 members.

**Waterdown** — RASC-Hamilton Centre, P.O. Box 1223, L0R 2H0, Eric Golding.

**Waterloo** — RASC-Kitchner-Waterloo Centre, 114 Westvale Drive, N2T 1J2, Paul Bigelow, (519) 888-7516.

### QUEBEC

**Montreal** — RASC-Le Soc. de Astronomie-Montreal, Casier Postal 206, Ste. Michael, H2A 3L9, Mark Gelinas.

**Montreal** — RASC-Montreal Centre, P.O. Box 1752, Station B, H3B 3L3, Louie Bernstein, (514) 845-2612. Founded 1918, 140 members. Observatory with Celestron 14.

**Ste. Foy** — RASC-Quebec Centre, Casier Postal 9396, G1V 4B5. Founded 1942, 75 members.

### NOVA SCOTIA

**Halifax** — RASC-Halifax Centre, 1747 Summer Street, B3H 3A6, Douglas Pitcairn, (902) 463-7196. Founded 1955, 160 members.

### PRINCE EDWARD ISLAND

**Summerside** — Athena Community Astronomy Club, P.O. Box 2500, C1N 4L9. 50 members.

### NEWFOUNDLAND

**St. John's** — RASC-St. John's Centre, c/o P.O. Box 944, Mount Pearl, A1N 3C9, Peter Allston.

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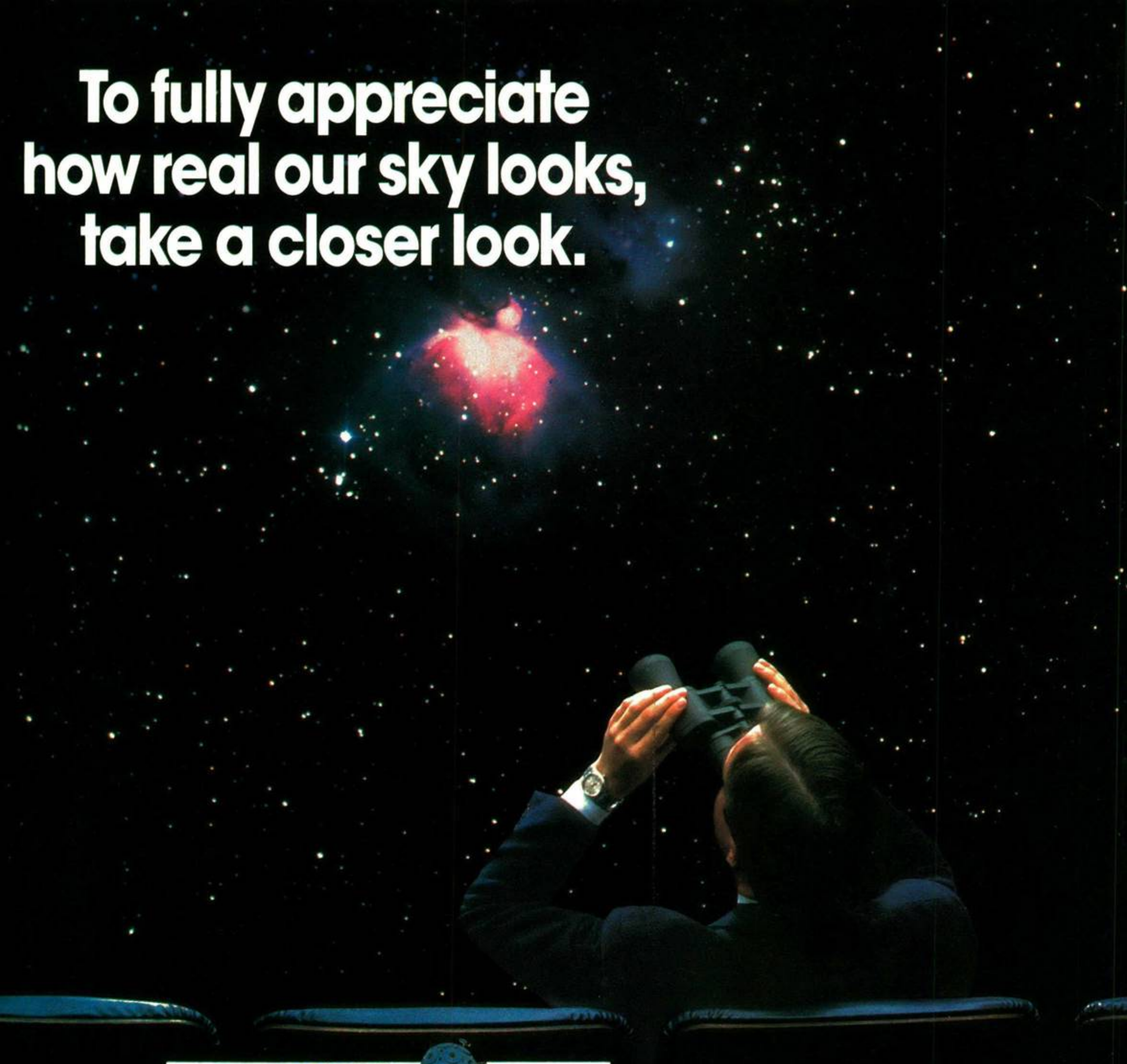

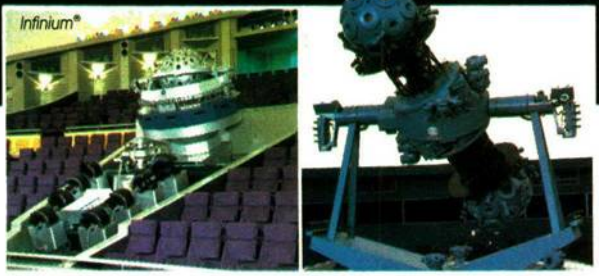

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